Social, Economic, and Spatial Perceptions of Gray Seal (Halichoerus grypus) Interactions with Commercial Fisheries in Cape Cod, MA

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Dr. Michael Orbach, Advisor

April 2014

Masters project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment of Duke University

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ABSTRACT

After more than 40 years of protection via the Marine Mammal Protection Act, the gray seal (*Halichoerus grypus*) population of the northwest Atlantic has increased considerably. Over the same period, commercial fisheries have boomed, and recently busted, in productivity and profitability. Although commercial fishermen will admit to overfishing, many believe the current abundance of gray seals prevents exploited fish stocks from recovering. In this study, commercial fishermen in Cape Cod were surveyed to assess their perceptions of the local gray seal population and economic costs associated with gray seal interactions. Additionally, a quantitative overlap analysis was performed to examine the extent to which commercial fishing and gray seal behaviors overlap in space and time. Results from the survey showed that 1) commercial fishermen are most concerned with the impacts of gray seals on local marine ecology than impacts on individual fishing operations; 2) both perceptions and impacts of gray seals could fluctuate seasonally; 3) gray seals could pose serious financial threats to commercial fishermen; 4) commercial fishermen would be willing to assist in data collection on the gray seal population; and 5) commercial fishermen believe that gray seals should be managed in the best interest of fisheries and ecosystem health. Results from the spatial overlap analysis corroborate survey results, and indicate potential for overlap between gray seal and fisheries to be greater in summer months than winter months. Overall, this study provides insights for understanding the views held by commercial fishermen, a key stakeholder group involved in this issue, which should be considered when weighing options for mitigating interactions between gray seals and commercial fisheries in Cape Cod.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

I. INTRODUCTION

Fishermen Call for Action

The rapid recovery of gray seals (*Halichoerus grypus*) in U.S. waters has been a cause for both celebration and concern. While proponents of animal welfare and conservation point to the population's recovery as a success of the Marine Mammal Protection Act of 1972 (MMPA; 16 U.S.C. 1361 *et seq*.), members of the commercial fishing community in Cape Cod, Massachusetts have expressed their fear that the reemergence of gray seals threatens the existence of their profession. Put politely, the commercial fishermen want to see fewer gray seals.

Breaking into national news outlets as early as 2006 (Associated Press), this issue has transformed into a hotly contested debate between advocates of commercial fishing and advocates of nature preservation. In the past year, Cape Cod fishermen have been centerpieces of provocative articles in the New York Times (Bidgood 2013) and Boston Magazine (Starobin 2013), increasing public awareness of the gray seal "problem." The story becomes more contentious as it proliferates, pitting the widely held conservation attitudes of the general public against the utilitarian mindsets of fishermen with the fate of both the fishing industry and gray seals possibly at stake (Lavigne *et al*. 1999).

Between 1888 and 1962, an estimated 72,000 to 135,000 seals were harvested in Massachusetts and Maine as part of a bounty system for pelts and meat, and to reduce seal competition with fisheries (Lelli *et al*. 2009). Over the past 40 years, however, the protection of gray seals in the U.S. under the MMPA has allowed their population to rebuild in southern New England from a maximum of 2,010 animals in 1994 to more than 15,000 in 2011 (NMFS 2012). After a bout of overfishing from the late 1980s to the early 1990s, lucrative cod and groundfish fisheries struggle despite attempts to rebuild as required by the Magnuson-Stevens Fishery Conservation and Management Act (Benoit and Swain 2008). Although commercial fishermen tend to admit that overfishing caused the collapse of fisheries, they contend that the increase in seals now prevents the stocks from recovering due to increased predation. Additionally, commercial fishermen frequently claim that seals interfere with commercial fisheries for dogfish, monkfish, and skate (Personal observation). Overall, many fishermen perceive the gray seal population

to exacerbate poor fishing conditions, and have vocalized the need for gray seal management, by which they mean a culling of or reduction in the seal population, to assist in fish stock recovery and reduce seal-fishery interactions.

Implications of the MMPA

The MMPA places management authority of gray seals under the jurisdiction of the National Oceanic and Atmospheric Administration (NOAA), and more directly its subsidiary National Marine Fisheries Service (NMFS). The MMPA most famously placed a prohibition on "taking", defined as the harassing, hunting, killing, or attempting to do any of the aforementioned (Sec. 3(13)), of all marine mammals in U.S. waters (Sec. 101(a); Sec. 102(a)). The Congress found that populations of marine mammals were threatened or endangered due to man's activities, and a main objective of the MMPA is to keep marine mammal populations above the point where their function in the ecosystem is compromised; this point is defined as the optimum sustainable population (OSP) (Sec. 2(2)). OSP refers to the number of animals that maximizes the stock's productivity within the bounds of the carrying capacity of the ecosystem (Sec. 3(9)). The MMPA also reflects the Congressional view that marine mammals carry esthetic and economic significance, and as such that keeping marine mammal stocks at or above OSP should only be considered when consistent with maintaining ecosystem health and stability (Sec. 2(6)).

To synthesize, marine mammal populations should be maximally productive so long as they can be supported by the healthy, stable ecosystem in which they occur. Therefore, the success or failure of the marine mammal management per the MMPA largely depends largely on the scientific community's definition of ecosystem health and stability and determination of a stock's OSP (Baur *et al*. 1999). Otherwise, the MMPA has a conservative bias toward marine mammals, in that if there is ever any uncertainty about the consequences of an action toward marine mammals, regardless of their status, decisions will always favor the marine mammals until the ecosystemic effects of an action are better understood (Baur *et al*. 1999).

One major exception to the taking prohibition of the MMPA is for commercial fishermen, who can become authorized to take marine mammals incidental to fishing activities. In 1994, the MMPA was amended to allow commercial fishermen to non-lethally deter any marine mammal from damaging gear or catch (Sec. 101(a)(4)). Further,

the 1994 amendments established a means to govern incidental takes in commercial fisheries through Take Reduction Plans (TRP) to be implemented by Take Reduction Teams (TRT) (Sec. 118). Before the adoption of the 1994 amendments, solely the Secretary of Commerce was deemed responsible to prescribe regulations that pertained to incidental taking (Sec. 103(a)) by issuing permits (Sec. 104). The 1994 amendments also mandated the Secretary of Commerce to annually publish a list of fisheries (LOF) categorized by the frequency that they incidentally kill or injure marine mammals (Sec. 118(c)(1)). Participants in category I and II fisheries, which correspond to "frequent" and "occasional" incidental catch of marine mammals, respectively, must annually register with the Marine Mammal Authorization Program (MMAP) to claim exemption from the taking moratorium posed by the MMPA (Sec. 118(c)(3); NOAA Fisheries 2014a). Per the incidental taking amendments, vessel owners are required to report incidental marine mammal mortalities or injuries to the Secretary of Commerce within 48-hours of a trip's end (Sec. 118(e)).

Finally, the 1994 amendments require TRPs to be designed for depleted marine mammal stocks and category I or II fisheries listed in the LOF, with an immediate goal of reducing incidental mortality to levels below the potential for biological removal (PBR), which is the maximum number of animals that may be taken from a stock without compromising its ability to reach or maintain OSP (Sec. 3(20)), and a long-term goal of reducing the rate of incidental taking toward zero (Sec. 118(f)). The 1994 amendments also mandated the completion of stock assessments for all stocks of marine mammals in the U.S. (Sec. 117(a)). Stock assessments should be based on the best available science, and include information on population and productivity trends, interactions with humans and commercial fisheries, and stock status relative to OSP.

According to the 2013 LOF (Federal Register 2013), the Northeast sink gillnet fishery is listed under category I, indicating frequent interaction with gray, harbor, harp, and hooded seals, harbor porpoise, and various cetacean species, and enrollment in the Atlantic Large Whale TRP (ALWTRP) and Harbor Porpoise TRP. Additionally, the Northeast American lobster trap/pot fishery is listed under category I for interaction with harbor seal, humpback whale, minke whale, and North Atlantic right whale and enrollment in the ALWTRP. The Northeast bottom trawl fishery is listed under category

II for occasional bycatch of gray, harbor, and harp seals, harbor porpoise, and various cetacean species, and involvement in the Atlantic Trawl Gear TRT.

Despite being frequent bycatch in Northeastern fisheries, the levels of incidental takes of gray seals pose no major threat to gray seals. According to the latest published stock assessment for gray seals (NMFS 2012), neither the level of human-caused mortality nor the stock's status relative to OSP is known. However, the stock assessment provides that human-caused mortality is considered negligible relative to the size of the stock, which is thought to be increasing at an unknown rate.

Characterizing Interactions between Gray Seals and Fisheries

The problems fishermen claim gray seals pose to their businesses can be understood in terms of biological and operational interactions. Biological interactions describe the ecological competition between fisheries and seals for the same resources (i.e. fish) (Northridge and Hofman 1999). For instance, gray seals could consume commercial fish species, fish species necessary to build commercial stocks, or transmit parasites to fish, thereby affecting the number and quality of fish to be landed by fisheries and their associated revenues (Lavigne 2003). Weighing between 550 and 880 pounds as adults and consuming 4 to 6 percent their body weight in food daily (NOAA Fisheries 2013), thousands of gray seals foraging in recovering fishing grounds could mathematically seem like a cause for concern. Conversely, biological interactions could deprive seals of food necessary for survival or recovery, and affect the marine ecosystem in subtle ways by altering trophic cascades through fishing (Pauly *et al.* 1998).

While this concept seems straightforward, the extent to which these interactions adversely affect fisheries or seals is confounded by the complexity of the marine food web, which is comprised of interactions between numerous species and not just commercial fish stocks, gray seals, and fishermen in isolation (Lavigne 1996). Further, combining food web complexities with dynamic abiotic factors (i.e. climate change) that influence species distribution and biology makes any linear cause-and-effect relationship between abundances of seal and individual fish species increasingly difficult to detect (Mangel and Hofman 1999; Benoit and Swain 2008). Thus, the effects of biological interactions are difficult to quantify considering the full suite of biotic and abiotic interactions and influences that can affect a species.

Operational interactions, on the other hand, verifiably affect both commercial fisheries and gray seals. These interactions include instances of depredation, when seals damage or take fish from fishing gear that would otherwise be landed and sold and thereby affect the value of catch (Figure 1) (Rafferty *et al*. 2012; Northridge and Hofman 1999; Read 2008). By tampering with fish, seals can cost fishermen through damage to previously sellable fish, damage to gear, and lost time or effort, for instance, picking through depredated fish or disentangling seals from nets. Instances of depredation can also result in serious injury or death for seals, as they are frequently incidentally captured in commercial fisheries (Read 2008).

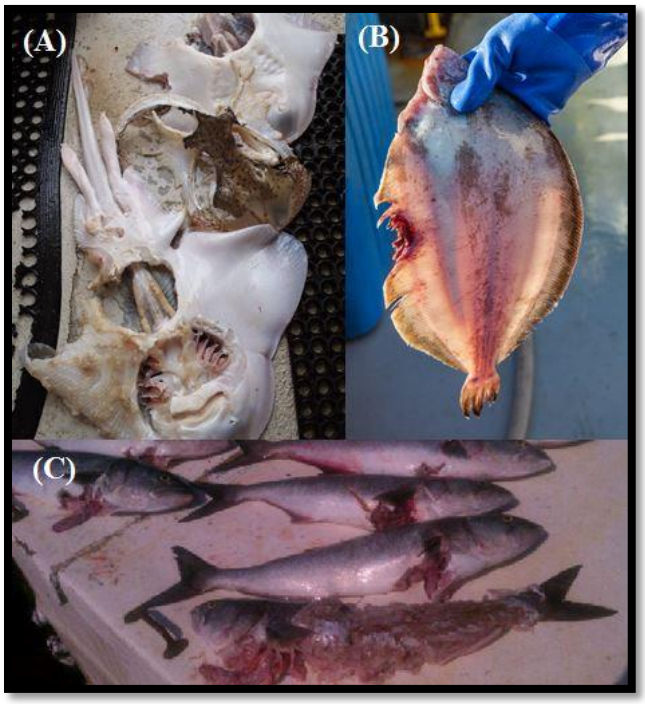

Figure 1. Evidence of gray seal depredation on (A) skate, (B) flounder, and (C) bluefish

Photos courtesy of Claire Fitz-Gerald, David Hills, and Nancy Civetta

The effects of operational interactions on gray seals are made quantifiable through incidental catch reports and observer reports as mandated by the MMPA (Sec. 118(e); Sec. 118(c)(3)(B)). The effects of operational interactions on fisheries can be quantified in monetary terms. For instance, one study estimated the value of catch discarded in a

gillnet fishery because of spiny dogfish and harbor seal depredation to find that fishermen incur small financial costs relative to the value of their entire catch (Rafferty *et al*. 2012). Depredation, however, is not the only source of verifiable financial loss that can occur when fishermen interact with predators. This study did not account for other potential costs, such as gear damage or lost time that could accrue from interactions with predators. Furthermore, since this study was conducted, gray seals have emerged as the primary source of competition for fishermen, potentially displacing harbor seals as the largest population of concern in southern New England.

Statement of Purpose

As early as 1979, conferences have been held to determine research needs for understanding fundamental ecologies of marine mammals on the U.S. east coast, with more recent conferences focusing on interfacing stakeholders, scientists, and policy makers amidst growing concerns regarding the impacts of seals (Bogomolni *et al*. 2010). Despite attempts to constructively address this emerging issue through stakeholder and research meetings, the confluence of the stalled fish stock recovery and the increasing expenses due to seal predation has led commercial fishermen to advocate for seal herd reduction in Cape Cod. The current adamant stance of commercial fishermen in favor of culling the seal population has been met by considerable criticism in scientific and public spheres, forming a climate of debate regarding the efficacy of a cull. Some scientific publications suggest marine mammal culls could benefit fisheries (Swain *et al*. 2011; Trzcinski *et al.* 2006; Chouinard *et al.* 2005), while others suggest culls could either have no effect or contribute to the downfall of fishing (Morissette *et al*. 2012; Yodzis 1998; Butterworth *et al*. 1988). In the public arena, some consider proposed culls of seals a scapegoat for decades of poor fishery management (Pannozzo 2013; Holt and Lavigne 1982). Groups such as the Humane Society of the United States and the International Fund for Animal Welfare (IFAW) insistently protest seal hunting in Canada, while groups such as the Seal Abatement Coalition (www.sealabatement.com) have formed around calls for gray seal population control in Cape Cod.

The purpose of the research reported here is not to debate the logistical merits or flaws of a gray seal cull or to prescribe management, but rather to convey the range of perceptions held by a stakeholder group involved in this issue. Although the general

sentiments of the Cape Cod's commercial fishing community are well stated in media, there have been no formal attempts to document the precise concerns of commercial fishermen regarding the impacts of gray seals on commercial fishing. By gleaning information about why some commercial fishermen perceive gray seals negatively, scientific endeavors can be directed to investigate more critical, possibly unobvious, aspects of interactions between commercial fisheries and gray seals. Additionally, an improved understanding of how fishermen perceive economic impacts of gray seals can support resource managers and fishermen alike to most efficiently mitigate operational interactions. Finally, an investigation of the spatial and temporal dynamics of fisheries and gray seals can illustrate how the two overlap, providing an empirical basis to validate the occurrence of interactions and further inform science, stakeholders, and the policy and management process.

II. METHODS

Study Site and Subject Population

Historically, Georges Bank (Figure 2) serves as a primary fishing grounds for many of Cape Cod's commercial fleets, as it is favorable habitat to valuable fisheries species, including groundfish, cod, skate, and monkfish (GBCFGS 2010). Muskeget and Monomoy Islands (Figure 2), upon which Cape Cod's primary gray seal colonies reside, are proximally close to the fishing grounds. Sable Island (Figure 2) lies to the southeast of Nova Scotia, Canada, and contains a large portion of Canada's estimated 348,999 gray seals (NMFS 2012).

Like many towns in Cape Cod, Chatham and Harwich (Figure 2) have rich histories as productive fishing centers. Although the vibrant cod fisheries of old have all but vanished, fishing remains an integral part of the towns' economies and identities. Even since the collapse of the fisheries in the late 20th century, from 1997 to 2006, groundfish accounted for the most and second-most valuable landings in the ports of Chatham and Harwich, respectively (GBCFGS 2010). Fishing is not the sole enterprise of these towns, however, as Chatham and Harwich are popular summer tourism destinations, causing their populations to seasonally double and triple, respectively (GBCFGS 2010).

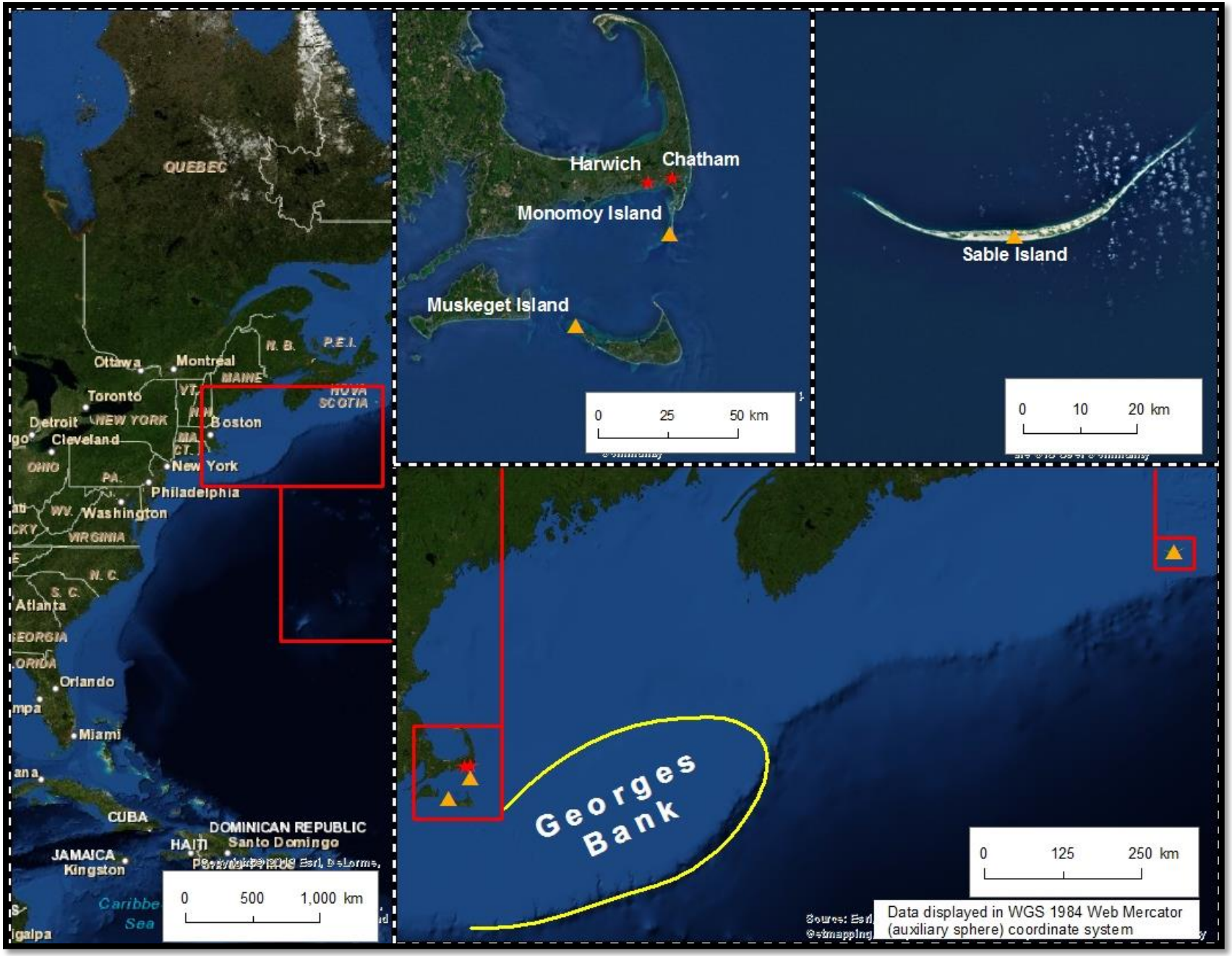

Figure 2. Map of study area

The Cape Cod Commercial Fishermen's Alliance (CCCFA; formerly the Cape Cod Commercial Hook Fishermen's Association) serves Cape Cod's small-boat fishing community by providing a forum for engagement in policy discussions and financial support for quota leasing.[1] Additionally, the CCCFA manages the Georges Bank Cod Fixed Gear Sector (GBCFGS), a membership-based cooperative that is allotted a collective total allowable catch for cod and multi-species groundfish. Many fishermen, sector members and non-members alike, from Chatham, Harwich and other nearby towns are familiar with and utilize the services of the CCCFA.

In December of 2006, the CCCFA organized a meeting between fishermen, policy makers, researchers, and environmental stakeholder organizations to initiate a collaborative research effort centered on understanding the ecological role of seals in local and regional waters (Nichols *et al.* 2011). The meeting resulted in cooperation between fishermen and researchers, allowing researchers access to important areas off Monomoy via fishing boats, and an avenue for constructive communication between fishing, science, and policy sectors. More recently in March of 2013, the CCCFA sponsored an meeting called the Outer Cape Seal Symposium, which brought together various local stakeholders, from fishermen to seal-watching tour operators, "to learn about the exploding gray seal populations in [Cape Cod's] waters and how this could affect the future of Cape Cod" (CCCFA 2013). The primary purpose of the symposium was to initiate a dialogue centered on the importance of understanding the ecosystemic effects of the growing gray seal population for consideration of future management.

Social Perception Survey

To capture the perceptions of commercial fishermen toward gray seals, a structured survey was implemented between July 8 and August 15, 2013. Surveys were administered opportunistically to individuals willing to participate. Surveys were completed independently or in the presence of a survey administrator at the CCCFA office in Chatham. Respondents, reached through contacts at the CCCFA, were active commercial fishermen primarily from ports in Chatham and Harwich and represented

[1] In 2005, the CCCFA established the Cape Cod Fisheries Trust to assist local small-scale commercial fishermen in attaining affordable quota, which helps small-scale fishermen remain an integral part of local communities on Cape Cod. For more information, visit: www.capecodfishermen.org/fisheries-trust

nearly every commercial fishery in the region. The questions and intent of the survey were formed following informal conversations with commercial fishermen about their interactions with gray seals. Understanding that fishermen generally viewed the resident gray seal population as a nuisance, the survey sought to uncover more precise reasons fueling this conception. One goal of the survey was to establish a baseline assessment of fishermen interactions with gray seals in a defined time period. Since the survey was conducted in the summer of 2013, all questions about fishing activities and gray seal interactions were answered relative to the calendar year 2012 to gather responses pertaining to a full year.

The survey (Appendix A) was comprised of 27 questions organized into several sections. The first section (Questions 1-5) established respondent demographics based on their tenure and participation in commercial fisheries, gear types used, the size of and position (captain or owner/operator) on fishing vessels, and months fished.

The second section (Questions 6-11) concerned the general nature of respondent interactions with gray seals. Respondents were asked to indicate the number of seals they observe each month they fish, describe if and how the number of seals they observe while fishing has changed over time, and estimate the total population size of gray seals inhabiting Cape Cod to the best of their abilities. From a list comprised of common grievances deduced from informal conversations during survey development, respondents were asked to identify, in their opinion, the three greatest impacts that seals have on commercial fishing. Additionally, respondents were asked to identify three months they feel seals have the most noticeable impact on their fishing, and to rate their confidence in their abilities to distinguish seal depredation from that of other predators.

The third section (Question 12) aimed to estimate financial costs incurred by respondents because of gray seal interactions. Respondents were asked to identify up to three fisheries they participated in that were affected by seal interactions. Gear types used in each fishery was inferred by cross-referencing earlier responses (Question 3). For each affected fishery, respondents answered a series of 14 questions pertaining to the standard cost and frequency of operation and additional costs incurred due to interactions with seals. To establish a baseline for operational costs for each fishery, respondents were asked to provide estimates of the average cost for a trip (in terms of fuel, ice, bait, gear,

etc.) and the number of trips taken. To approximate the financial impact of seals on each fishery, respondents were asked to estimate the proportion of trips where seals depredated from their gear and the cost of such depredation, and the proportion of trips where any of their catch was infested with seal worm and the cost of the degraded fish quality. Respondents were also asked to list gears damaged by seal and repair costs, the number of man-hours and days-at-sea lost because of seal interactions or presence and opportunity costs, and distance traveled to avoid seals and excess fuel costs. This section was presented as a table, with rows corresponding to the cost questions and columns corresponding to affected fisheries, and the survey provided instructions and an example of how to complete the table.

The fourth section (Questions 13-19) addressed respondent opinions of gray seal research and information sources. Respondents were asked whether they believe researching the resident gray seal is important and to describe their opinion of the present state of data on local gray seals. Respondents were asked to rate various information sources on the quality of information they provide pertaining to fisheries. Finally, respondents were asked about their willingness and ability to host researchers and collect information on gray seals while fishing and their confidence in sharing the information they collect online.

The fifth section (Questions 20-27) addressed respondent perceptions of and positions on managing gray seals in Cape Cod. Respondents were asked whether seals should be managed and how management should consider the interests of various stakeholder and environmental entities. Respondents were also asked to describe their feelings about the current population size of the gray seals, and to provide their perceptions of the role of seals in the ecosystem. Finally, respondents were asked about the role stakeholders should play in managing the seal population, and whether they perceive the current state of gray seals as problematic. The survey concluded with a free response section where respondents were invited to elaborate on how their perceptions of seals have changed over time, or share any additional information. A short demographic section followed this section, where respondents indicated their gender and age.

Survey responses were aggregated and analyzed using all answers provided for each question, since surveys varied in completeness and the sample size was relatively

small (N = 43). In instances where respondents provided a multiple answers or a range as a response (i.e. circling choices 3 to 5 on a scale of 1 to 5), the midpoint of the range was used in analysis.

Seals-Fisheries Overlap Analysis

Fishing effort and seal "effort" (or spatiotemporal distribution) was compared in summer and winter seasons in a geographic space to quantitatively assess the extent to which fishing activities and gray seal behaviors overlap off of Cape Cod. Results from this analysis could be used validate the extent to which fishermen claim seal interactions negatively affect their businesses. Fishing effort information and seal telemetry data was gathered using the methodologies described below. Data organization and overlap analyses were based on methods of Cronin *et al*. (2012), who investigated overlap between gray seals and a trawl fishery off Ireland's west coast.

Fishing Effort Survey

A fishing effort survey (Appendix B) was used to generate a current metric of fishing effort to be used in the overlap analyses. This survey was administered primarily to gillnet fishermen on February 24, 2014 at the CCCFA office. The survey was designed to gather generalizable spatial and effort information for summer, May through October, or winter, November through April, fishing seasons in recent years (~2012 – present). Seasons were delineated following consultation with respondents, who generally recognize these two seasons of the fishing year. Respondents completed a separate survey for each season they fished. The spatial portion of the survey consisted of a map of Cape Cod and Georges Bank with prominent bathymetric contours and labeled reference points. The map was overlain with a grid, each grid cell measuring 10' latitude by 10' longitude. Respondents were asked to mark grid cells where they fish with an "X". Respondents were asked to approximate the number of trips taken in a season and the average duration of a trip (hours), and list gear types used and species targeted.

For each completed survey, fishing effort per marked grid cell was calculated using corresponding effort information. The number of trips was multiplied by trip duration to estimate the number of hours fished by the respondent in a season. In instances where respondents failed to provide either of these values, the mean value from

the respondent pool was used. In instances where trip duration was provided in terms of "days", values of 12- and 24-hours were supplemented for summer and winter surveys, respectively, in recognition of the generally shorter trips in summer and longer trips in winter. When respondents provided a range of values for number of trips or trip duration (i.e. "80-90 trips" or "8-9 hours"), the middle value of the range was used. The total number of hours represented by a survey was divided by the number of grid cells marked in the spatial portion of the survey, resulting in a generalized metric of seasonal fishing effort in terms of hours per grid cell. For summer and winter seasons, survey responses were aggregated and linked to their corresponding grid cells using a geographic information system (GIS) format (ESRI ArcGIS v.10.2).

Gray Seal Tagging and "Effort"

As part of a collaborative study spearheaded by the Northwest Atlantic Seal Research Consortium (http://nasrc.whoi.edu), which includes researchers from NOAA's Northeast Fisheries Science Center, Duke University, Woods Hole Oceanographic Institution, and IFAW among others, seven GSM/GPRS tags (SMRU Instrumentation, St. Andrews, Scotland) were deployed on gray seals captured off Chatham from June 12 to 17, 2013. Briefly, these tags use a variety of sensors to collect high-resolution movement and dive data for seals as well as ocean temperature measurements during dives. The data are initially archived on the tags during at-sea periods and then transferred off of the tags for analysis and land-based storage using the available GSM mobile phone network when seals return to the beach and haul out. A research team captured gray seals from a tidal sandbar in Chatham Harbor using a 300' long 30' deep seine net of 12" mesh and transported animals to a worksite for biological sampling and tag affixation. Capture methods were based on those in Jeffries *et al.* (1993). GSM/GPRS tags were attached to the dorsal neck/head region of the animal's fur using an epoxy-based adhesive as in Fedak *et al.* (1983).

Telemetry data from these seals were uploaded into a Microsoft Access database, along with data from an eighth gray seal tagged in September 2012. Seal data points for each season were queried by month to comprise summer (May through October) and winter (November through April) seasons as delineated by fishing effort survey respondents. Data were uploaded into a GIS (ESRI ArcGIS v.10.2) as lines, connecting

points of sequential dates/times in each seal in season. Sporadic data lines, resulting from temporary tag malfunctions or the combination of non-sequential date/time points, were removed from the data manually. Using the same grid cells and extent as the fishing effort survey, the total number of hours spent by seals in each grid cell was calculated to provide a metric of seal "effort" per season, and reflected in Figures 23 and 24.

Overlap Indices

Two analyses were conducted to assess the extent to which fishing and seal efforts overlap spatially in each season. Each overlap analysis compared the proportion of effort hours represented in a cell by fishermen (*Pf*) and seals (*Ps*). The first analysis, index of difference in spatial pattern (IDSP) (Eq. (1)), describes similarities in habitat use patterns of two "species." IDSP halves the sum of absolute value of differences in proportions of species habitat uses, *Pf* and *Ps*, resulting in an index ranging between zero and one, representing identical and completely different spatial patterns, respectively (Cronin *et al.* 2012). A similar metric has been used to investigate niche overlap of krill predators in Antarctica (Friedlaender *et al*. 2011). The second analysis, Morisita Horn Index of overlap (Eq. (2)), assesses overlap and possibly competition by multiplying proportional efforts of species in a cell, *Pf* and *Ps*, before aggregating values for the entire grid. Thus, only cells where both species occur (and can therefore compete) contribute to the aggregated index score of the entire grid, where scores near zero indicate low overlap and vice versa (Cronin *et al.* 2012). A variation of the Morisita Horn index has been used to model resource competition between seabirds and fisheries worldwide (Karpouzi *et al*. 2007).

(1)

$$IDSP = \frac{\sum |Pf - Ps|}{2}$$

(2)

$$Morisita\ Horn = \frac{2 \sum Pf\ Ps}{\sum Pf^2 + \sum Ps^2}$$

III. RESULTS

Social Perceptions Survey – Respondent Demographics

The survey was completed by a total of 43 respondents, all of whom were males, ranging between 2 and 50 years of experience as commercial fishermen, with an average tenure of 28.45 ± 11.43 S.D. years. Most respondents participated in multiple commercial fisheries, with dogfish, groundfish, striped bass, lobster, skate and monkfish among those reported most frequently (Table 1). Additionally, most respondents reported using multiple gear types, with handlines, gillnets, clam rakes, and pots among those indicated most frequently (Table 2). Most respondents reported they fished from vessels between 36' and 45' in length (Table 3). Respondents identified themselves as captains, owner/operators, or both captains and owner/operators of the vessels they fished from in similar proportions (Table 4). Finally, respondent fishing effort increased in summer and peaked in August, when 100% of respondents indicated they fished (Table 5). Most respondents reported they fish in summer months, especially May through October, and only 20 respondents indicated they fished in every month.

Table 1. Fisheries represented by survey respondents

Fishery	**Respondents (N = 43)**
Black seabass	1
Bluefin tuna	11
Bluefish	4
Conch	1
Dogfish	25
Groundfish	19
Haddock	1
Lobster	16
Mackerel	1
Menhaden	4
Monkfish	15
Oysters	2
Quahog	11
Scallop	6
Scup	2
Skate	16
Softshell Clam	12
Squid	5
Striped Bass	19

Table 2. Gear types represented by survey respondents

Gear Type	Respondents (N = 43)
Benthic longline	5
Clam rake	15
Fish weir	3
Gillnet	19
Handline (rod and reel)	25
Harpoon	4
Pots (lobster or conch)	11
Scallop dredge	9
Trawl	4

Table 3. Vessel lengths represented by survey respondents

Vessel Length Class	Respondents (N = 43)
< 20’	3
21’ – 25’	5
26’ – 30’	1
31’ – 35’	7
36’ – 40’	14
40’ – 45’	13
46’ – 50’	3

Table 4. Role classifications represented by survey respondents

Role Classification	Respondents (N = 43)
Captain	14
Owner/Operator	16
Captain and Owner/Operator	13

Table 5. Months fished by survey respondents

Months Fished	Respondents (N = 43)
January	26
February	23
March	30
April	36
May	39
June	40
July	42
August	43
September	42
October	40
November	32
December	28

Perceptions of Gray Seal Population Abundance and Impacts on Commercial Fishing

When asked to report the number of gray seals observed offshore while fishing, respondents generally indicated they observed fewer gray seals in winter months November through April compared to summer months (Figure 3). Respondents most frequently reported seeing more than 1,000 gray seals per month while fishing in July and August, and less than 500 seals in preceding and following months. In winter months, November through February, respondents most frequently reported observing between 1 and 100 seals (Figure 3).

When asked how the resident gray seal population has changed over time, the majority of respondents indicated that there are many more gray seals now than there were in the past (Figure 4). Respondent population estimates for gray seals residing in Cape Cod ranged from 2,000 to 500,000 animals, with a mean estimate of 59,909.09 ± 116,432.74 S.D. The majority of estimates ranged between 10,000 and 20,000 animals and most of the remaining estimates were greater than 20,000 animals (Figure 5).

Respondents identified predation on commercial fish stocks, predation on forage fish stocks, and depredation on fish captured in gear as the top three impacts of gray seals on commercial fishing (Figure 6). Among responses not listed (categorized as “other”), respondents indicated that seals disturb fish schooling and spawning behaviors (N = 5),

contaminate water through fecal pollution (N = 1), and alter the marine ecosystem by destroying commercial fish stocks (N = 1).

Respondents were generally very confident in their abilities to distinguish seal bite marks from bite marks of other species, indicating their ability to accurately assess damages to catches caused by seals rather than other predators (Figure 7). Finally, respondents indicated that gray seals had the greatest impact on their commercial fishing in summer months, peaking in July (Figure 8). In winter months November through April, seals were reported to have the least noticeable impact on fishing, and five respondents indicated that seals had no impact on their commercial fishing.

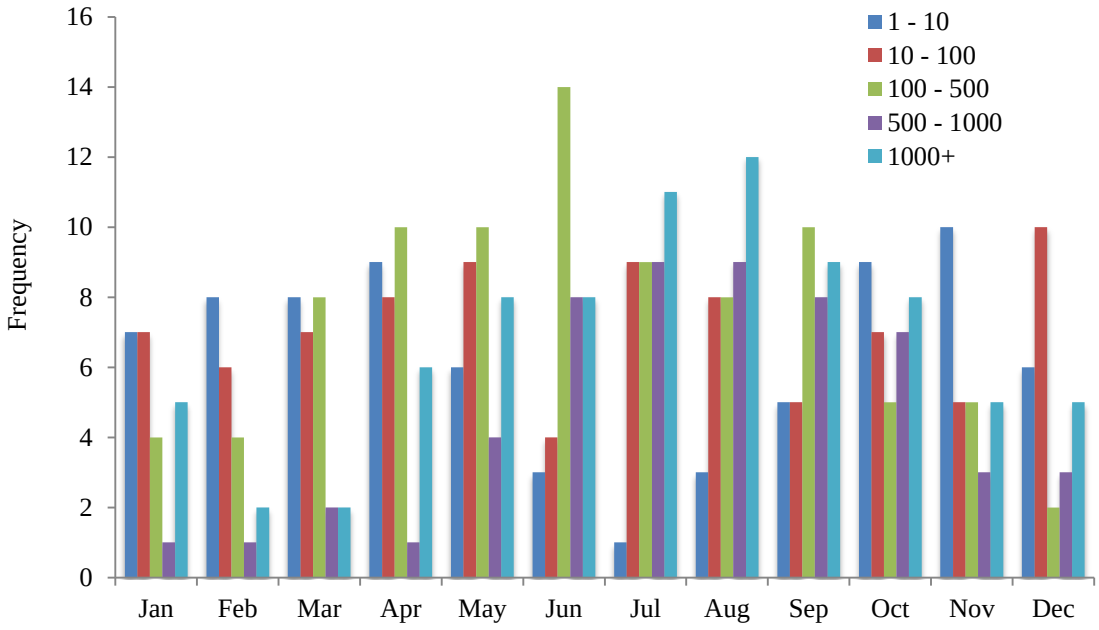

Figure 3. Number of gray seals observed offshore by respondents (N = 41) while fishing each month

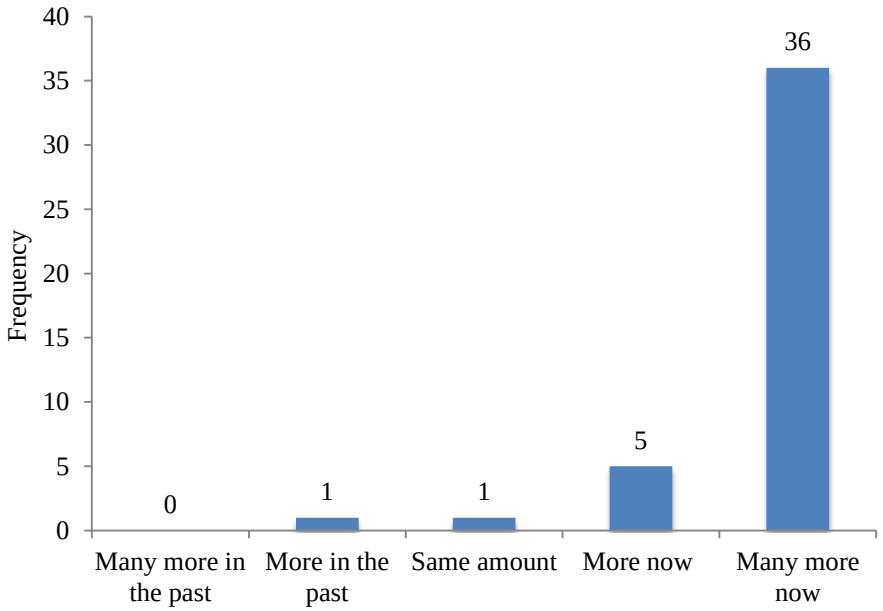

Figure 4. Respondent (N = 43) perceptions of present gray seal population size relative to the past

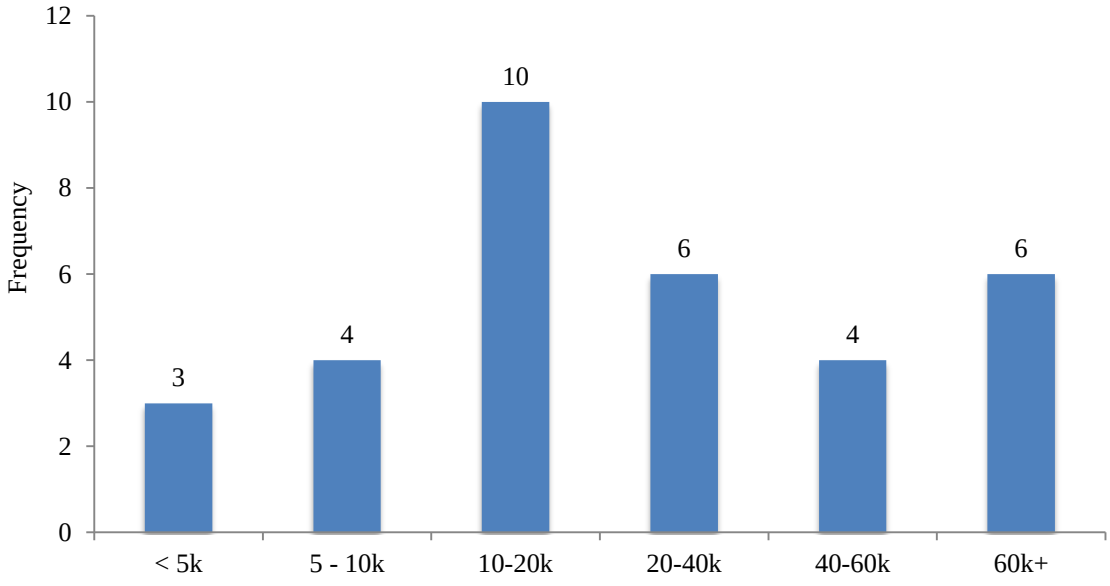

Figure 5. Respondent (N = 33) estimates of current gray seal population in Cape Cod

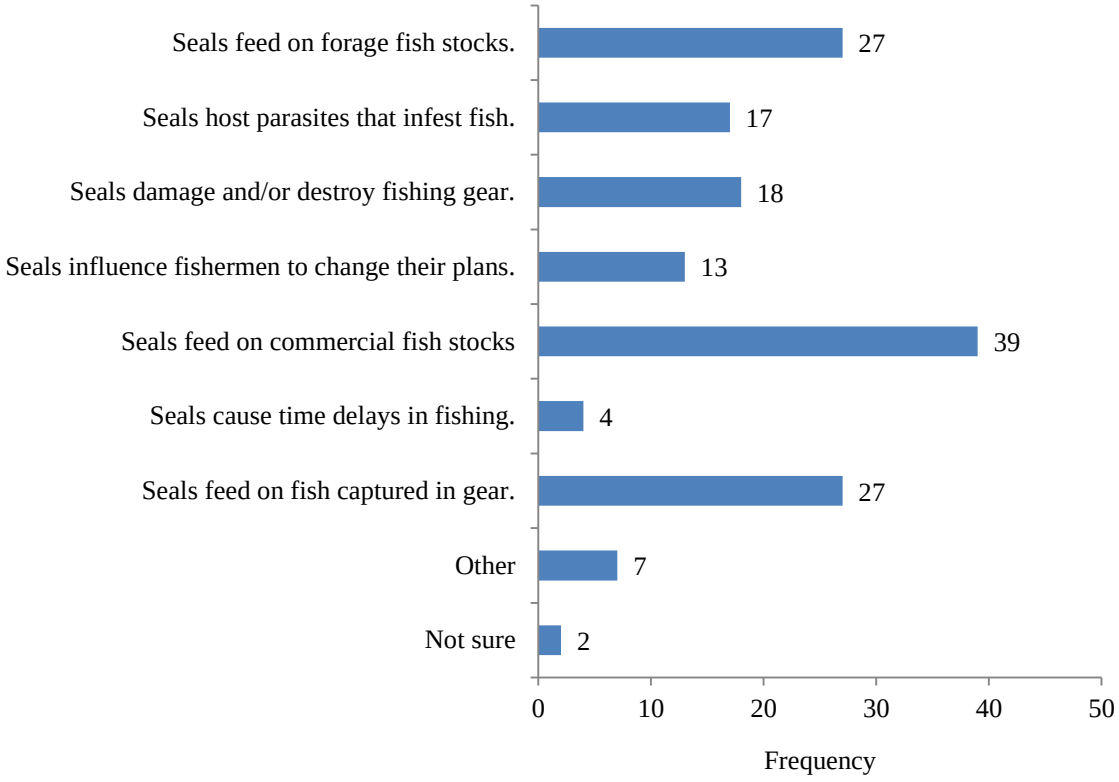

Figure 6. Respondent (N = 43) perceptions of greatest impacts of gray seals on commercial fishing

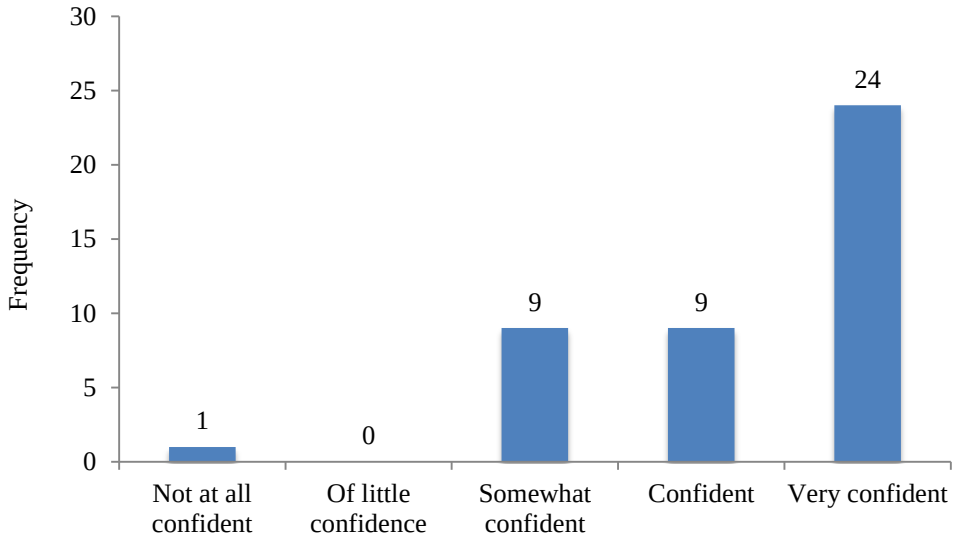

Figure 7. Respondent (N = 43) confidence in ability to distinguish seal bite marks from other predators

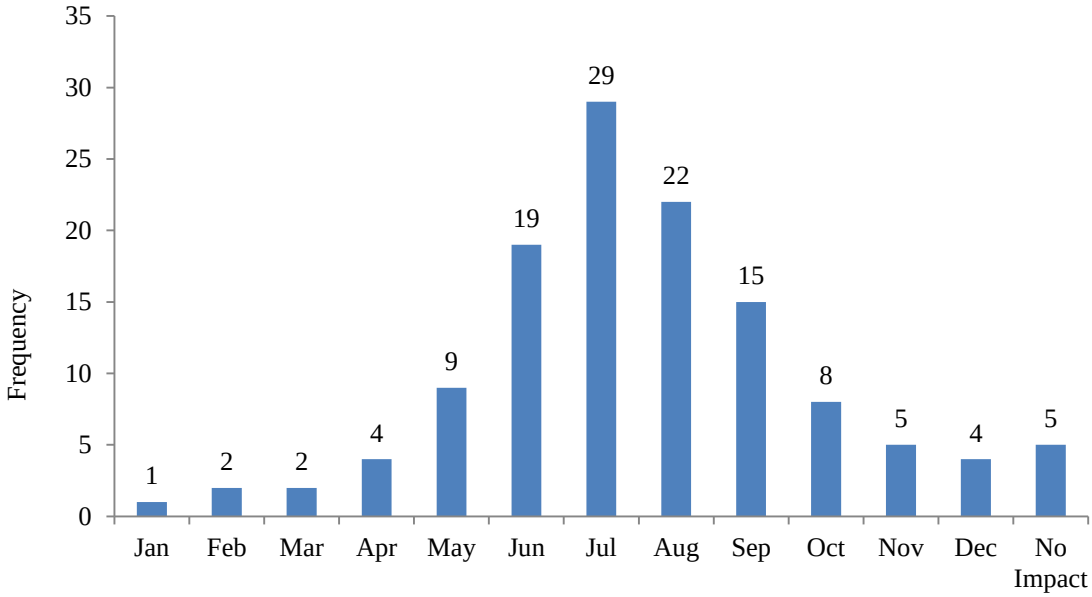

Figure 8. Respondent (N = 41) perceptions of months when seals have most noticeable impact on commercial fishing

Perceptions of Economic Costs Incurred by Gray Seal Interactions

Thirty-seven respondents provided 73 total responses pertaining to economic costs associated with gray seal interactions. Fisheries described most frequently included lobster, cod and groundfish, skates, dogfish, and monkfish (Table 6). Some respondents combined financial cost estimates for multiple fisheries that use the same gear (for instance, if they participated in gillnet fisheries for monkfish, dogfish, and skates), causing the number of fisheries represented (N = 80) to exceed the number of cost estimates provided (N = 73). Because of these instances where information was combined among multiple fisheries, gear types were inferred using information provided from Question 3. Among these inferred gear types, gillnets were represented the most, followed by handlines and lobster pots (Table 7). To avoid resampling in instances where one response pertained to multiple fisheries, the following economic impacts were assessed for the inferred gear types instead of individual fisheries.

Based on these 73 responses, a total of $1,887,940 USD in costs was estimated due to seal interactions with fisheries in 2012 (Figure 9). Gillnet fisheries (N = 25)

comprised more than half the total cost estimate, while handline (N = 24), longline (N = 7) and pot (N = 11) fisheries reported the least costs. Fisheries listed under "other" (clam rake, fish weir, harpoon, scallop dredge, and trawl) comprised the second greatest cost despite consisting of the fewest responses (N = 6). Fish weirs (N = 2) incurred the majority of costs for these "other" fisheries.

For all fisheries, lost time and effort was the largest source of financial losses due to gray seals, comprising nearly 60% of all costs (Figure 10). Depredation comprised the second largest constituent of total costs, making up approximately 29% of all costs reported. Costs of gear repair/replacement, extra fuel, and catch affected by seal worm comprised the smallest portions of financial costs associated with gray seal interactions across all responses. Table 8 provides a summary of all costs for each gear type.

Gillnet fisheries for dogfish, groundfish, monkfish, and skate reported more than $1 million USD in costs associated with seal interactions. The greatest source of cost for gillnet fisheries was lost time and effort, which was reported in 15 responses, totaling a loss of $560,000 USD (53.1%) for these fisheries. The second largest source of costs for gillnet fisheries was depredation, which was reported in 19 responses, totaling a loss of $326,500 USD (30.9%). On average, depredation occurred on 38.81 ± 28.06% of commercial trips (N = 20), while 23.21 ± 36.67% of trips were reported to have any catch infested with seal worm (N = 14). Gillnets were frequently reported to be damaged or in need of repair (N = 16), and some respondents reported travelling up to 100 additional miles to avoid seals.

Fish weir and clam rake fisheries were the only fisheries listed under "other" to list costs associated with gray seal interactions. The only cost reported by clam rake fisheries was a $25 USD copay for a doctor visit to treat an infection "likely caused by seal feces." Weir fisheries reported over $600,000 USD in costs associated with seal interactions, and the majority of this cost was in lost time and effort ($406,000 USD, 65.9%). Depredation comprised the second largest source of costs, a total of $195,000 USD (31.7%). Gears damaged by seals included weir nets, which cost a combined $15,000 USD to replace or repair.

Longline fisheries for dogfish, groundfish, and skate reported over $100,000 USD in costs incurred via gray seal interactions. Lost time and effort was the greatest

constituent of these costs, totaling $90,000 USD (88.6%). The second largest cost source for longline fisheries was seal worm infestation, which totaled $10,000 USD (9.8%) in losses. Only two responses reported any level of depredation and only one response indicated damage to gear, citing "a small amount of hooks" that needed to be replaced. Respondents reported travelling up to 80 additional miles to avoid seals.

Handline fisheries for bluefish, dogfish, fluke, groundfish, monkfish, scup, skate, and striped bass reported $86,830 USD in costs associated with seal interactions. Lost time and effort comprised the greatest portion of these costs, totaling over $75,000 USD (86.4%). Depredation and extra fuel costs were the next largest cost sources, totaling $6,300 USD (7.3%) and $4,020 (4.6%) respectively. Only one response indicated any level of seal worm infestation in catches and only five listed gears damaged by seals, which included rods, lines, lures, hooks, and bait. Responses reported travelling up to 20 additional miles to avoid seals.

Lobster pot fisheries reported $28,110 USD in costs incurred due to gray seal interactions, the least of all inferred gear types. Depredation was the greatest source of these costs, totaling $21,000 USD (74.7%), while gear repair and replacement comprised $7,050 USD (25.1%) of these costs. Pot fisheries reported no time and effort losses or instances of seal worm, and only two responses indicated any level of depredation. Responses reported trap doors, entry heads, and buoys as items needing repair or replacement.

Table 6. Fisheries represented in economic section

Fishery	Respondents (N = 37)
Bluefin tuna	1
Bluefish	2
Cod/Groundfish	13
Dogfish	12
Fish weir	1
Fluke	1
Lobster	11
Mackerel	1
Monkfish	10
Scallop	1
Scup	1
Skate	13
Softshell Clam	1
Squid	1
Striped Bass	11
TOTAL	**80**

Table 7. Inferred gear types represented in economic section

Gear type	Respondents (N = 37)
Clam rake	1
Fish weir	2
Gillnet	25
Handline (rod and reel)	24
Harpoon	1
Longline	7
Pots	11
Scallop dredge	1
Trawl	1
TOTAL	**73**

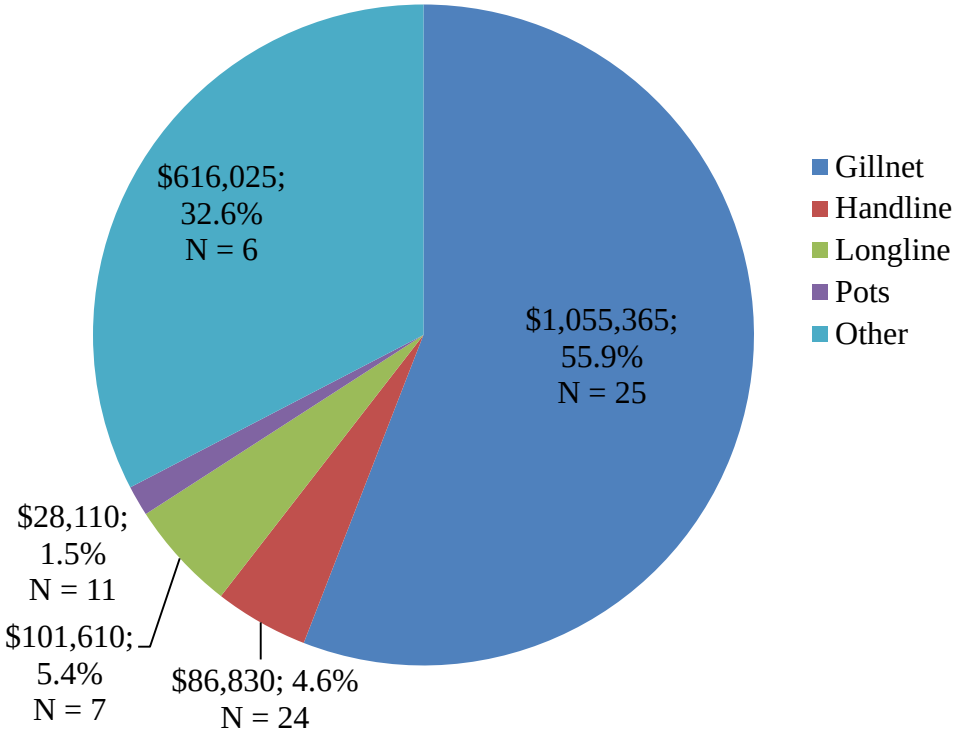

Figure 9. Total costs broken down by gear type

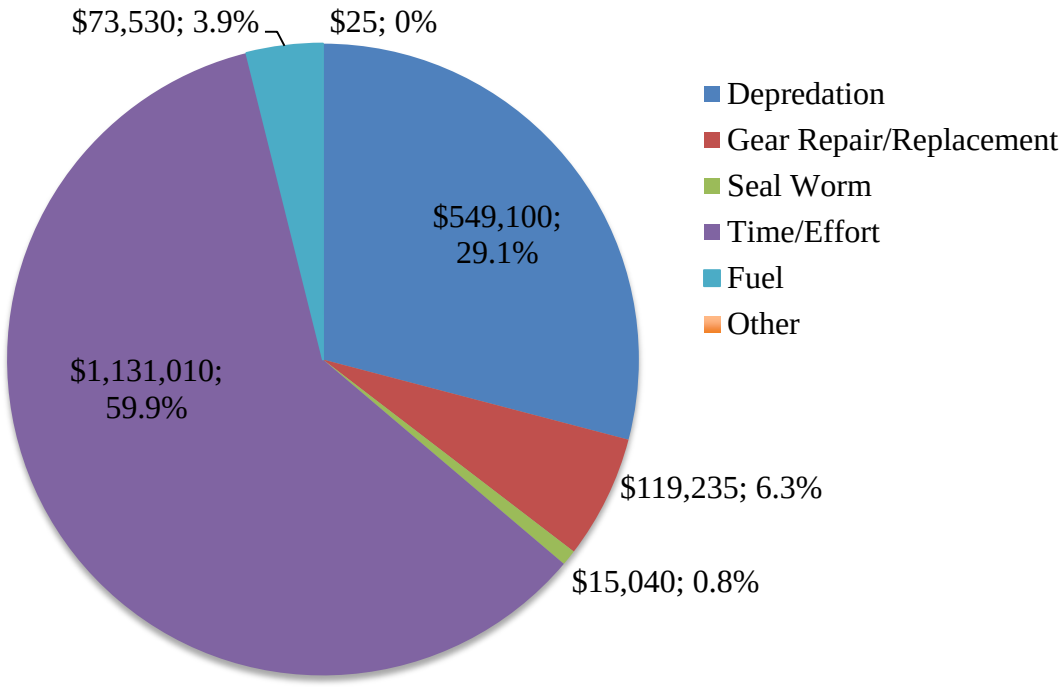

Figure 10. Total costs broken down by sources

Table 8. Summary of economic costs incurred by gear types

2012 Fisheries Information		Gillnets (N = 25)	Handlines (N = 24)	Longline (N = 7)	Pots (N = 11)	Other (N = 6)
% trips w/ dep-redation	Mean ± S.D.	38.81 ± 28.06	11.125 ± 25.10	4.29 ± 7.87	1.82 ± 4.05	50.00 ± 57.74
	Min. – Max.	0, 100	0, 100	0, 20	0, 10	0, 100
	N reported	20	16	7	11	4
Cost ($) of depre-dation	Sum	326,500	6,300	3,00	21,000	195,000
	Mean ± S.D.	16,325.00 ± 23,889.70	420.00 ± 792.10	50.00 ± 83.67	1,909.09 ± 6,007.57	39,000.00 ± 76,517.97
	Min. – Max.	0 - 100,000	0 - 3,000	0 - 200	0 - 20,000	0 - 175,000
	N reported	19	15	6	11	5
Gear damage	Gears listed	Gillnets	Rods, lures, line, bait	Hooks	Trap doors, entry heads, buoys	Weir nets
	N reported	16	5	1	2	2
Cost($) of gear damage	Sum	95,675	1,500	10	7,050	15,000
	Mean ± S.D.	6,378.33 ± 7,662.97	100.00 ± 165.83	1.43 ± 3.78	1,007.14 ± 1,830.40	3,000.00 ± 4,472.14
	Min. – Max.	0 - 30,000	0 - 500	0 - 10	0 - 5,000	0 - 10,000
	N reported	15	15	7	7	5
% trips w/ seal worm	Mean ± S.D.	23.21 ± 36.67	7.69 ± 27.74	32.00 ± 40.87	0	25.00 ± 50.00
	Min. – Max.	0 - 100	0 - 100	0 - 100	0	0 - 100
	N reported	14	13	5	7	4
Cost($) of seal worm	Sum	5,040	0	10,000	0	0
	Mean ± S.D.	420.00 ± 1,442.35	-	20,00.00 ± 4,472.14	-	-
	Min. – Max.	0 - 5,000	-	0 - 1,000	-	-
	N reported	13	13	5	6	2
Man-hours lost	Sum	905	20	6	0	200
	Mean ± S.D.	75.42 ± 82.64	1.54 ± 3.18	1 ± 2.45	-	40 ± 54.77
	Min. – Max.	0 - 200	0 - 10	0 - 6	-	0 - 100
	N reported	12	13	6	7	5
Days at sea lost	Sum	160	150	350	0	115
	Mean ± S.D.	11.43 ± 16.10	10.71 ± 40.09	50.00 ±132.29	-	23.00 ± 33.84
	Min. – Max.	0 - 50	0 - 150	0 - 350	-	0 - 75
	N reported	14	14	7	8	5
Cost($) of lost time/ effort	Sum	560,000	75,010	90,000	0	406,000
	Mean ± S.D.	37,333.33 ± 42,252.08	5,000.67 ± 13,495.77	15,000.00 ± 32,093.61	-	81,200.00 ± 116,048.27
	Min. – Max.	0 - 100,000	0 - 45,000	0 - 80,000	-	0 - 250,000
	N reported	15	15	6	8	5
Extra miles to avoid seals	Sum	514	90	117	35	18
	Mean ± S.D.	32.13 ± 36.24	6.43 ± 6.48	16.71 ± 29.48	5.00 ± 9.57	4.5 ± 9.00
	Min. – Max.	0 - 100	0 - 20	0 - 80	0 - 25	0 - 18
	N reported	16	14	7	7	4
Cost($) of extra fuel	Sum	68,150	4,020	1,300	60	0
	Mean ± S.D.	5,242.31 ± 5,528.41	365.45 ± 623.69	185.71 ± 376.07	8.57 ± 22.68	-
	Min. – Max.	0 - 15,000	0 - 2,000	0 - 1,000	0 - 60	-
	N reported	13	11	7	7	4
Other cost($)	Sum	0	0	0	0	25
	N reported	0	0	0	0	1
Total Costs ($)		**1,055,365**	**86,830**	**101,610**	**28,110**	**616,025**

Perceptions of Local Gray Seal Information and Participatory Data Collection

When asked whether it is important to collect data on the local gray seal population, only three respondents opined that data collection is not important (Figure 11). Most respondents described the current state of data on the gray seal population as either 'poor' or 'questionable,' while only a few felt that the present state of information was 'good' or 'excellent' (Figure 12). Respondents generally rated government resources as having the poorest quality of fisheries information compared to fishermen, which they rated as having the highest quality of fisheries information (Figure 13).

A majority of respondents indicated they would be willing to allow researchers onboard their vessels during commercial fishing trips to collect data about gray seal interactions with fisheries (Figure 14). Similarly, a majority of respondents indicated they would be willing and able to document gray seal sightings while fishing, and that they would be most capable to collect information regarding the date, time and location of sightings as well as the number of seal observed (Figure 15). More than half of respondents indicated they would be comfortable sharing their seal sighting information on the Internet (Figure 16). Of those who indicated they would be uncomfortable sharing their information online, unwillingness to disclose information related to fishing, uncertainty in how the data will be used, and confidentiality concerns were among the top reasons for their negative responses (Figure 16).

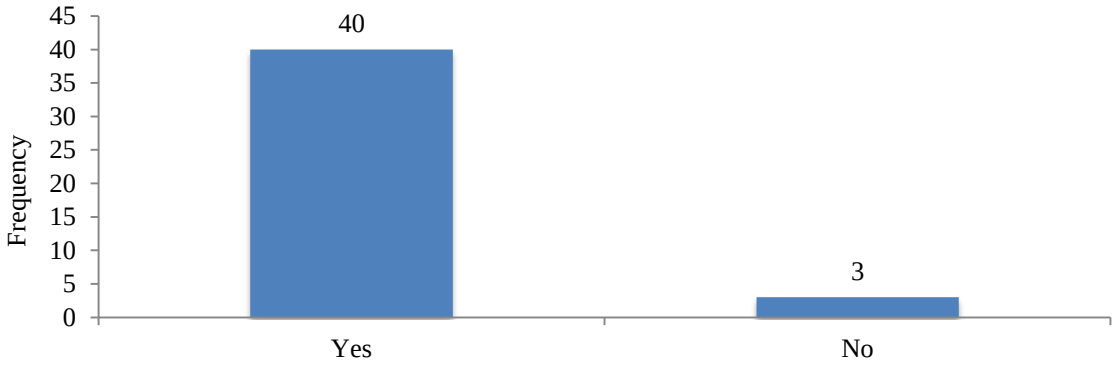

Figure 11. Respondent (N = 43) opinion on importance of gray seal data collection

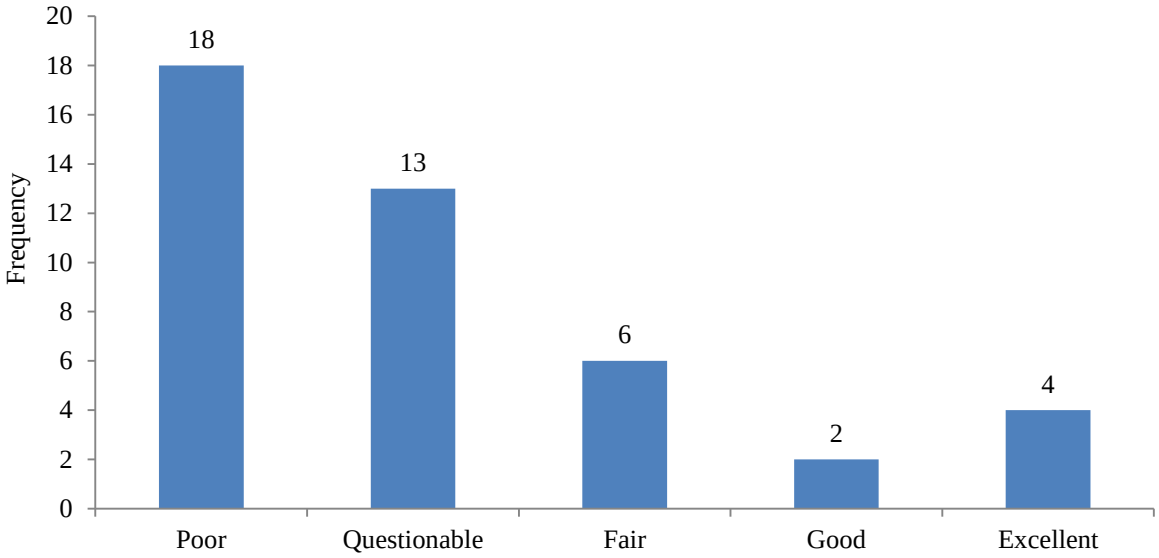

Figure 12. Respondent (N = 43) perceptions of current state of gray seal information

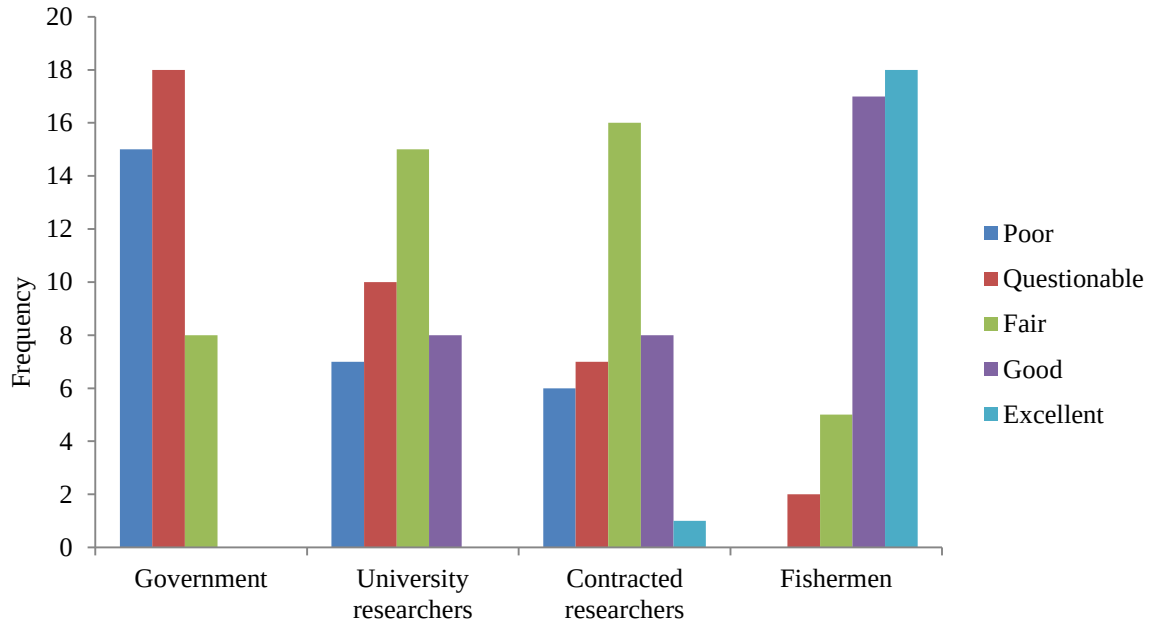

Figure 13. Respondent (N = 42) perceptions of fishing information quality provided by various resources

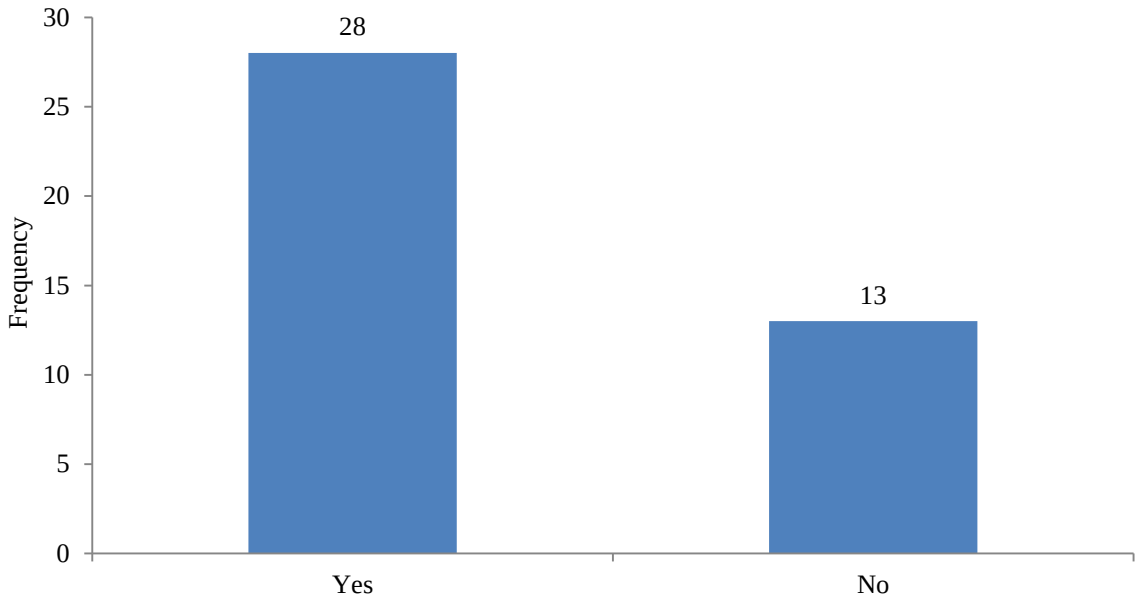

Figure 14. Respondent (N = 41) willingness to allow researchers onboard to collect seal data while fishing

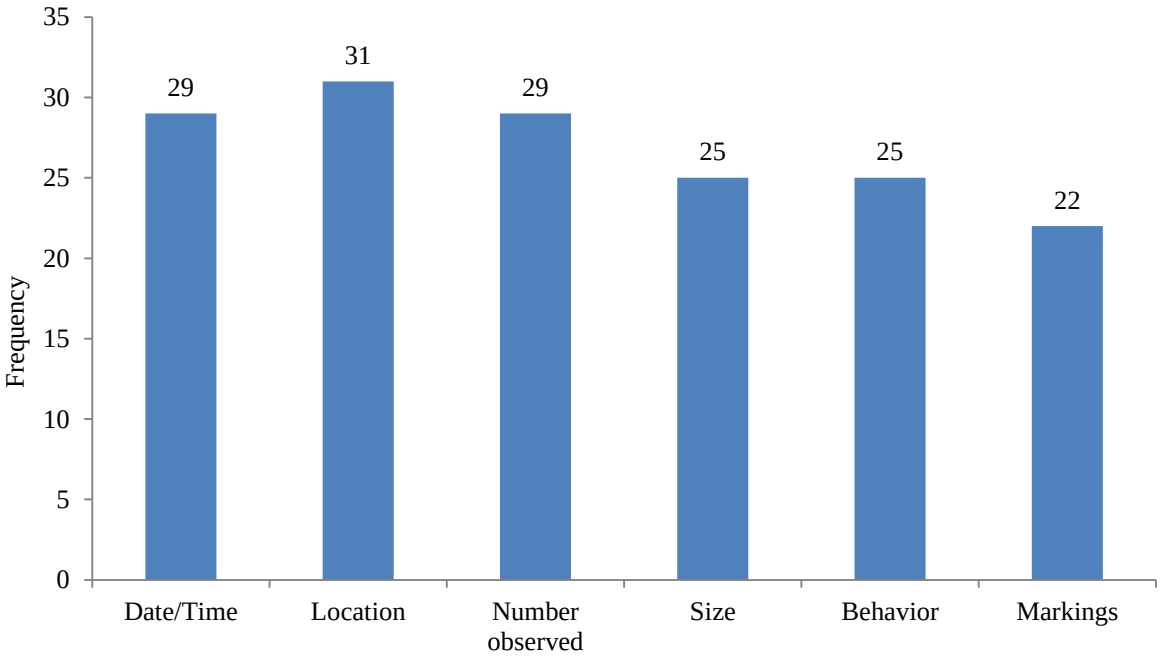

Figure 15. Seal observation attributes that respondents (N = 37) would be able to collect

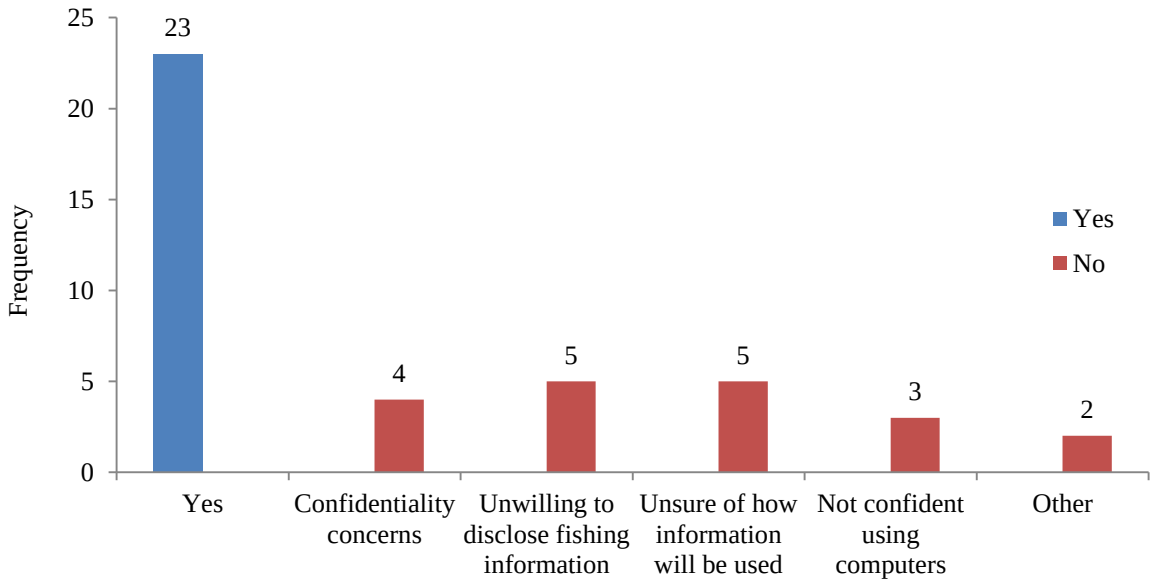

Figure 16. Respondent (N = 37) willingness to share seal sighting information on the Internet

Perceptions of Gray Seal Management in Cape Cod

When asked if gray seals should be managed in Cape Cod, all respondents (N = 40) answered affirmatively. Further, the majority of respondents indicated that the best interests of fisheries, the ecosystem, and the local community should be considered very important when deciding how to manage gray seals (Figure 17). Nearly all respondents felt that there are 'far too many' gray seals inhabiting Cape Cod and its adjacent waters (Figure 18).

The majority of respondents felt gray seals are a detriment to marine ecosystems rather than an integral, beneficial component. A majority of respondents opined that gray seals pose no benefits to marine ecosystems, while a few recognized their role in providing "ecosystem balance" or as prey for larger predators, namely great white sharks (Figure 19). Contrarily, a majority of respondents indicated that gray seals negatively affect ecosystems by consuming too many fish and affecting water quality through excessive fecal contamination (Figure 20).

When asked about the role fishermen should play in managing Cape Cod's gray seals, a majority of respondents expressed their willingness to participate in efforts to

reduce the herd (Figure 21). To a lesser extent, responses invoked advocacy or research assistance as appropriate roles for fishermen in managing this issue. Finally, when asked whether Cape Cod has a gray seal "problem," all respondents (N = 39) answered affirmatively.

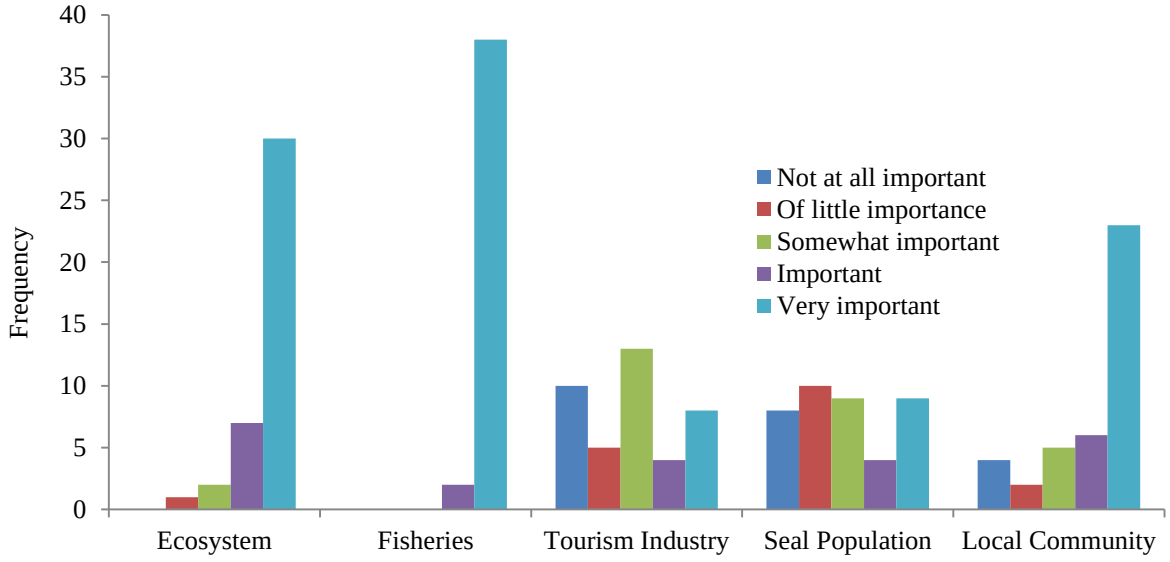

Figure 17. Respondent (N = 40) perceptions of the importance of various entities' considerations in seal management

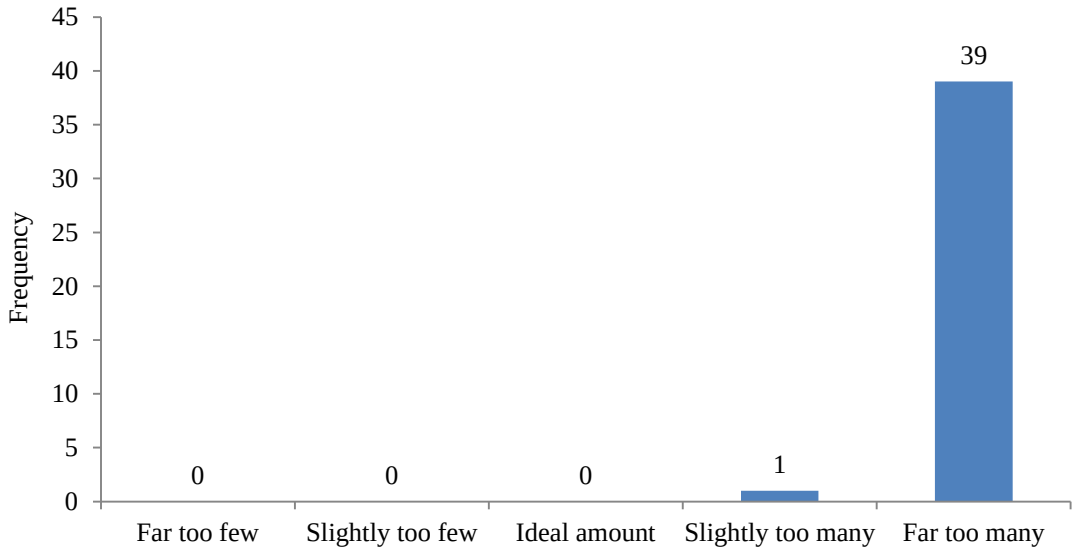

Figure 18. Respondent (N = 40) opinions of the present size of the local gray seal population

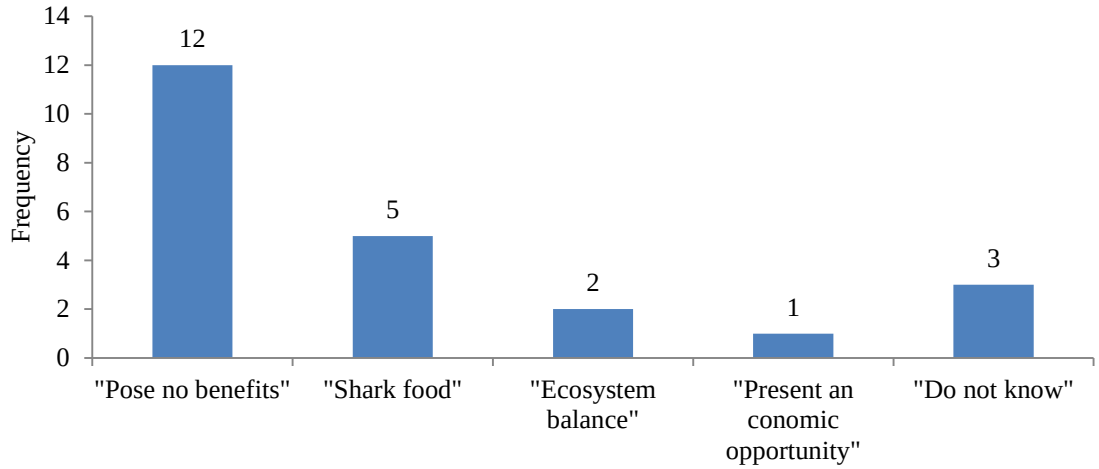

Figure 19. Ecosystem benefits presented by seals according to respondents (N = 21)

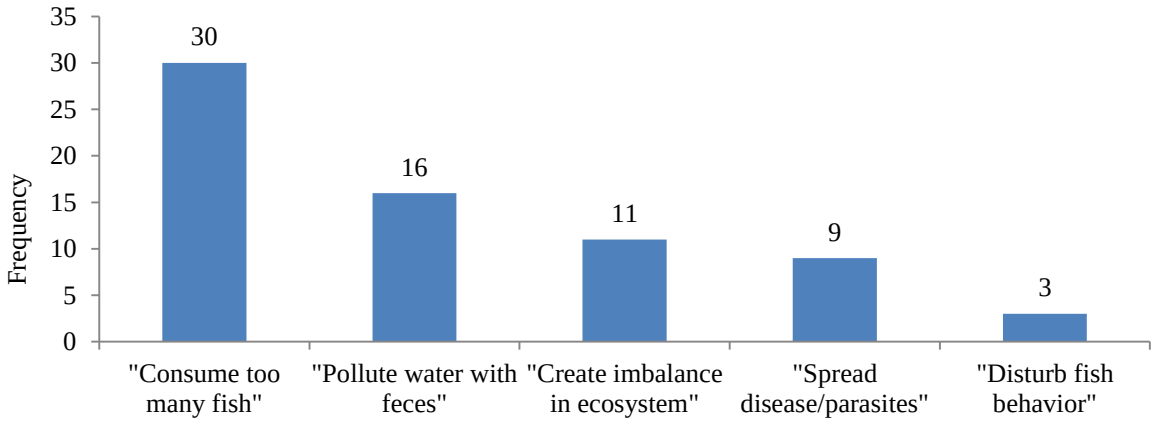

Figure 20. Ecosystem detriments presented by seals according to respondents (N = 36)

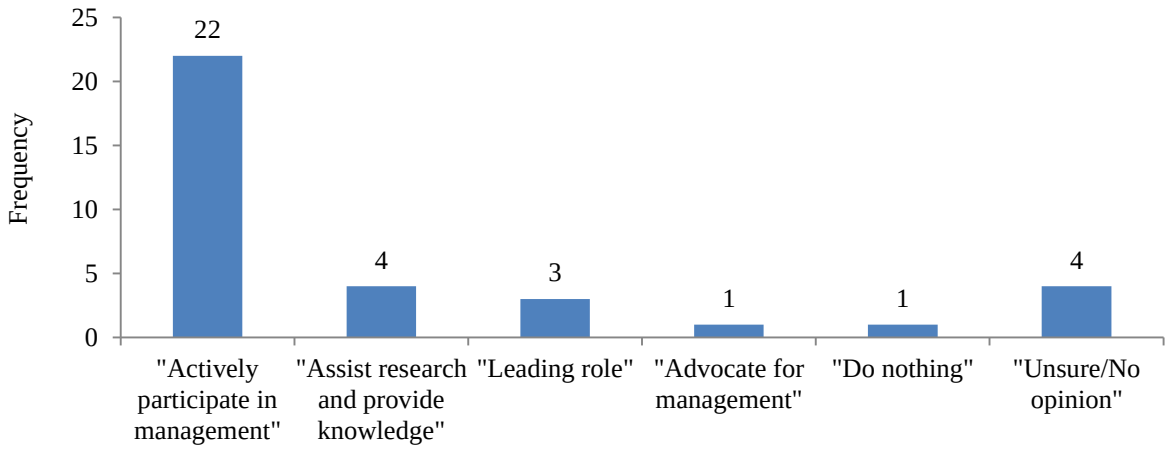

Figure 21. Respondent (N = 35) opinions of the role fishermen should play in managing seals in Cape Cod

Spatial Overlap Analysis – Fishing Effort

Summer fishing effort information was collected from 11 commercial fishermen. On average, these fishermen complete more than 90 trips apiece in a typical summer season, which last nearly 12-hours each and mostly target skate (Table 9). The final effort surface for the generalized, current summer season represented a total 11,630.90 hours of fishing activity. Winter fishing effort was collected from 8 commercial fishermen. On average, these fishermen complete more than 30 trips apiece in a typical winter season, which last over 24-hours each and mostly target monkfish. The final effort surface for the generalized, current winter season represented a total of 7,788.51 hours of fishing activity.

Table 9. Fishing effort survey summary

	Summer season (N = 11)	**Winter season (N = 8)**
Gear types represented	gillnet (10) trawl (1)	gillnet (7) trawl (1)
Species targeted	dogfish (4) groundfish (5) monkfish (5) scallop (1) skate (7)	groundfish (2) monkfish (7) scallop (1) skate (6)
Average number of trips	92.0 ± 17.06	33.21 ± 10.75
Average trip duration (hours)	11.45 ± 2.47	28.83 ± 6.20

Spatial Overlap Analysis – Seal Effort

Summer seal tag data was collected from 8 seals between Sept 10, 2012 and October 31, 2012 and June 13, 2013 and October 31, 2013. The final effort surface for the summer season represented a total of 23,165.73 hours of seal activity. In the summer,

seals were generally near shore, within approximately 10 miles, with the greatest concentration of effort occurring just off Chatham. Winter seal effort was collected from 7 seals between November 1, 2012 and March 21, 2013 and November 1, 2013 and March 22, 2014. The final effort surface for the winter season represented a total of 21,802.71 hours of seal activity. In the winter, the majority of seal effort was also near shore, but some seals moved onto Georges Bank, with one individual nearly completing a migration to Sable Island (Figure 22).

Spatial Overlap Analysis – IDSP and Morisita Horn Indices

Both the IDSP (0 = complete overlap, 1 = no overlap) and Morisita Horn (0 = no overlap, 1 = complete overlap) indices revealed that overlap between fishing and seal efforts is greater in the summer than winter (Table 10). Comparing proportional efforts by fisheries and seals in the summer season suggests that areas for the greatest potential overlap occur near shore and to the east of Chatham (Figure 23). In the winter season, fishing and seal efforts are dispersed further offshore to the south and east, respectively; however, overlap could occur near shore, like in the summer season, and also further to the south of Nantucket, where the majority of fishing effort is located (Figure 24).

Table 10. Index scores for seasonal fishing and seal effort overlap

	Summer	**Winter**
IDSP	0.736	0.767
Morisita Horn	0.353	0.208

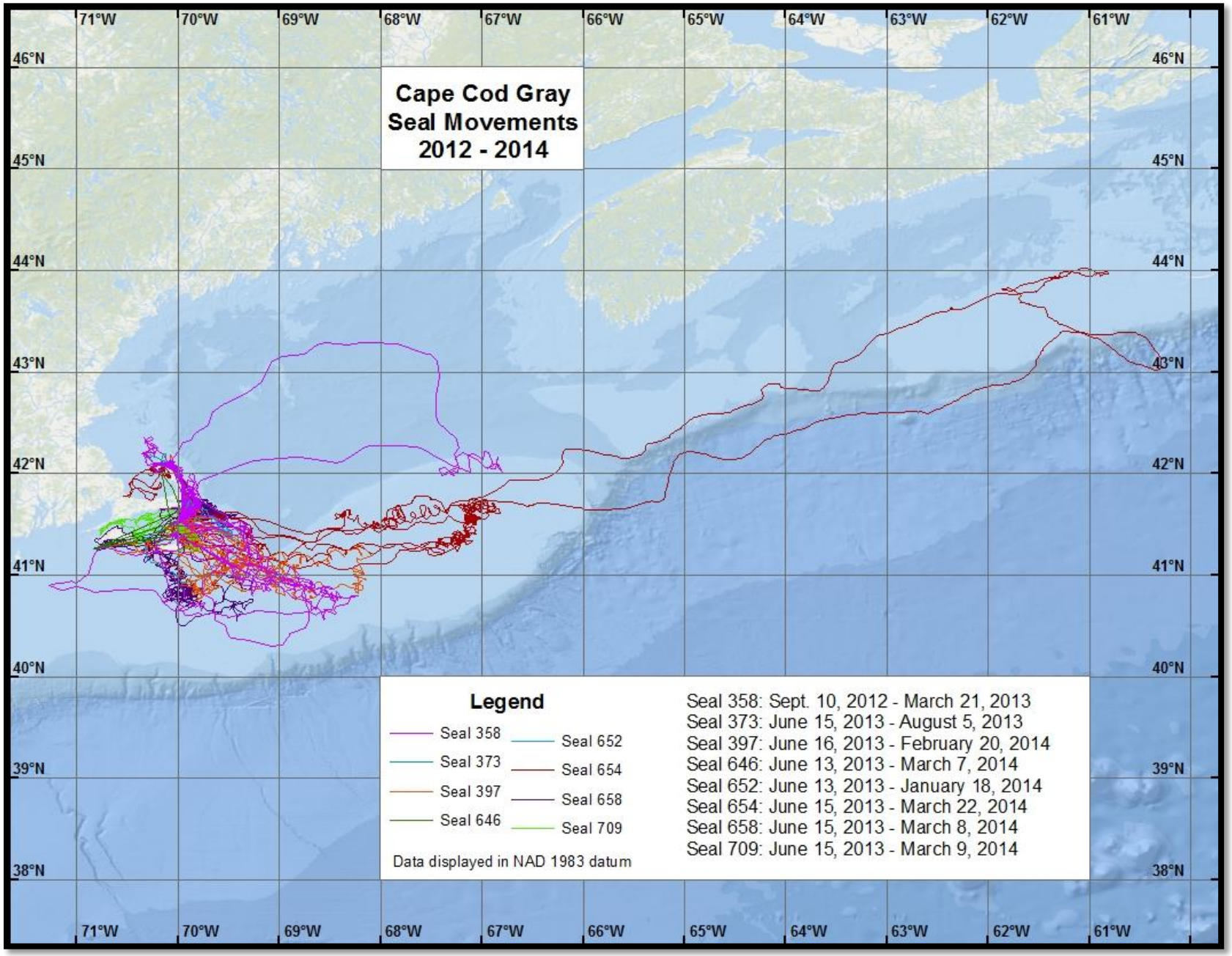

Figure 22. Cape Cod gray seal movements, 2012 - 2014

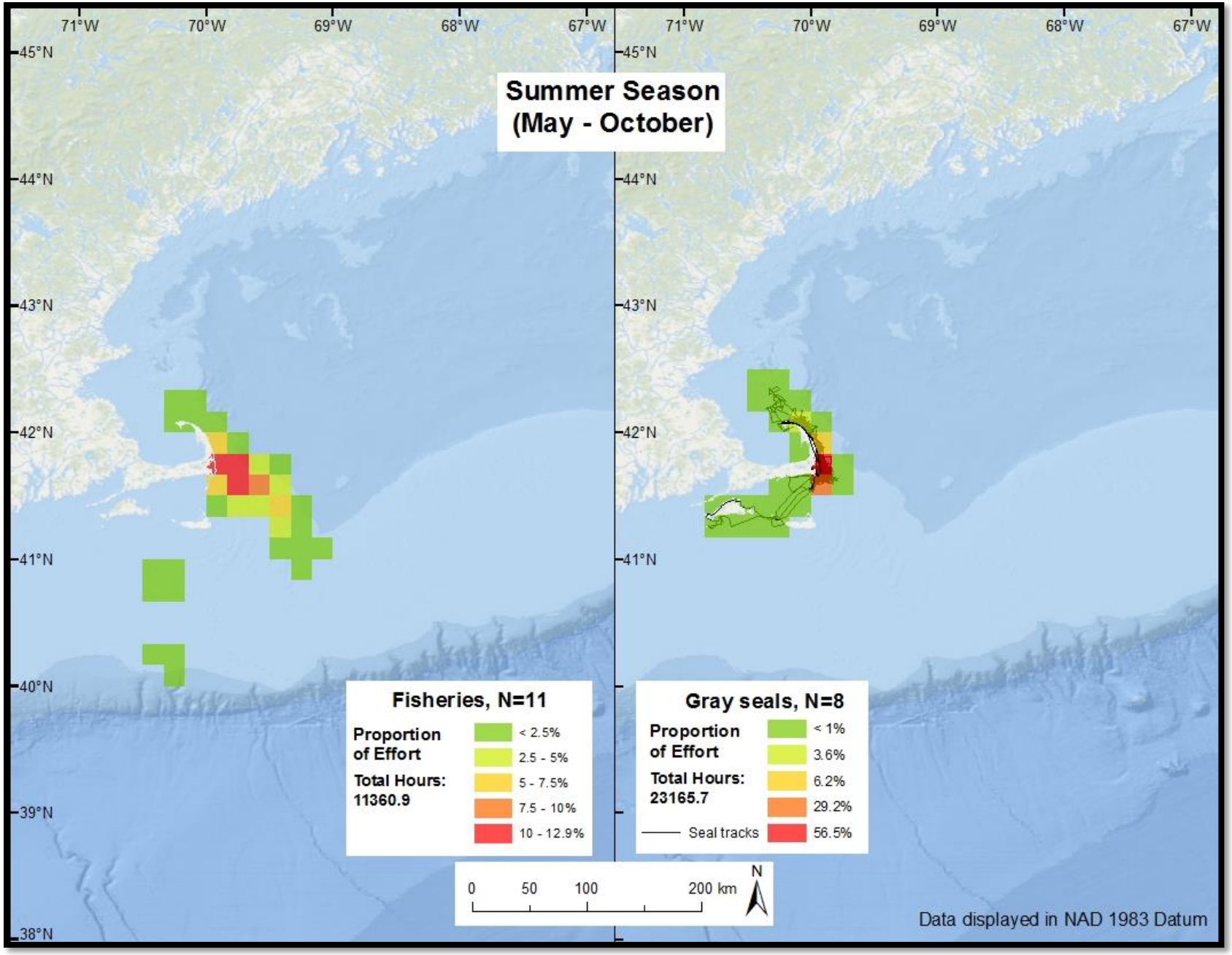

Figure 23. Summer season efforts of fisheries and gray seals off Cape Cod

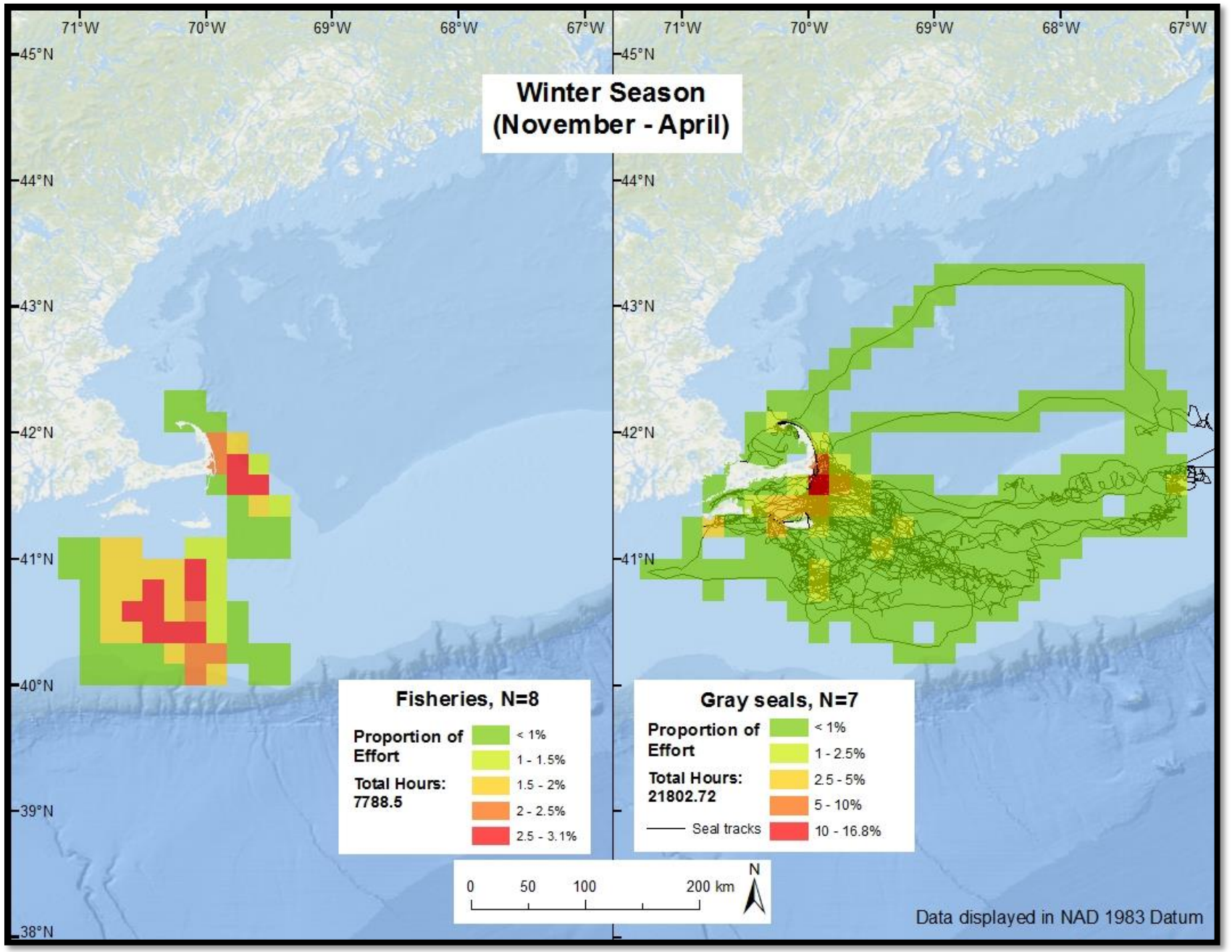

Figure 24. Winter season efforts of fisheries and gray seals off Cape Cod

IV. DISCUSSION

Perceptions of Severe Biological Impacts and Seasonality

Survey responses indicated that commercial fishermen are more concerned about the impacts of biological interactions between seals and fisheries than impacts of operational interactions. That seal predation on commercial and forage fish stocks were the two most frequently chosen impacts suggests that fishermen perceive the local population of gray seals as a viable threat to the longevity of the fisheries and marine ecosystems. To a lesser extent, respondents expressed concern over seals consuming fish from gear and damaging gear. This result emphasizes the need for a greater understanding of the local marine ecology, and specifically how seals, fisheries, and fish interact on a biological level, as echoed by one respondent:

> "When seals first reappeared in the Chatham area I was not concerned about them. The older fishermen though were very concerned they said the seals would wipe out all the inshore fisheries. At the time I felt they were over radical and hateful about seals. But they were right… The fact of the matter is that seals eat and replace the larger fish that lived in the area. The conservationists seem happy with the fact that the seals have eaten most of the fish in the area saying the seals will eat smaller items toward the base of the food chain. They seem to have no problem with the altered ecosystem the Cape used to be a place alive with many species of fish. Now [our] waters are inhabited with fluffy seals."

The sheer mass of fish consumed by gray seals could easily alarm fishermen. A crude comparison of commercial landings with consumptive scenarios of Cape Cod's gray seal population suggests that seals could be on par with all Massachusetts, let alone Cape Cod, fisheries in terms of landings (Table 11). Considering that the seal population has likely grown beyond the 2011 minimum estimate of 15,756 animals (but also that all seals are not uniform in size or daily food consumption), fishermen could be justifiably concerned that the present population of gray seals threatens fisheries and the ecological function of fisheries ecosystem. However, this cursory approach does not consider the composition of fish, commercial and non-commercial, in seal diets nor the role seals play

Table 11. Comparison of Massachusetts fisheries landings with scenarios of consumption by gray seals

Fishery	2012 Landings (pounds)*
Black sea bass	292,011
Bluefish	686,128
Cod	8,983,606
Founder (summer, winter, witch, yellowtail, Atlantic)	15,404,513
Haddock	4,180,085
Hake (red, silver, white)	12,511,244
Herring	81,781,049
Longfin squid	2,944,258
Mackerel	4,131,405
Menhaden	1,629,206
Pollock	11,147,701
Redfish	8,184,129
Scup	2,005,286
Skates	13,618,020
Spiny dogfish	13,130,539
Striped Bass	1,281,485
Total pounds landed	**181,910,665**

Cape Cod Gray Seal Consumptive Scenarios

Low Estimate

Seal Population[+]	15,756
Daily food intake[^]	4% weight
Weight[^]	550
Days	365
Total pounds consumed	**126,520,680**

Middle Estimate

Population	15,756
Daily food intake	5% weight
Weight	715
Days	365
Total pounds consumed	**205,596,105**

High Estimate

Population	15,756
Daily food intake	6% weight
Weight	880
Days	365
Total pounds consumed	**303,649,632**

*NOAA Fisheries (2014b); [+]NMFS (2012); [^]NOAA Fisheries (2013)

in managing predators of commercial fish (Lavigne 2003). Thus, an improved understanding of gray seal diets and ecological role is necessary to dispel or verify rumors that particular fish species and fisheries will see their demise due to seal predation.

The majority of responses pertaining to time and perceptions of gray seals indicated summer months as those when more seals are observed and seals have the most noticeable impacts on commercial fishing. This suggests that adverse interactions with

gray seals could be a perceived as a seasonal issue for fishermen. This notion of seasonality is corroborated by the results of the spatial overlap analysis, which concluded that overlap, and thus interactions, are more likely to occur in summer due to similarities in spatial patterns between fishermen and seals. Seasonality could also be an artifact of increased fishing effort in the summer, as indicated by respondents. One respondent noted that gray seals presented a formidable problem in winter months as well:

> "In March 2005 about 25 [nautical miles] east of Chatham I happened upon a spawning aggregation of redfish in 110 fathoms of water. That fishery provided myself and my crew great opportunity for 3 years in the months of January through April. Around February 2009 we were happened upon by some grey seals. From that day on the fishery rapidly diminished to a point where the seals are actually there before the fish awaiting their arrival. I also spent 20 years targeting spawning aggregations of cod and pollock. In the winter months one area after another became overrun with greys around the same time the fish would arrive. They're great hunters and never forget an opportunity. When I say it's too late to show this type of habitual activity to science I'm saying I can't show what's already occurred. The seals work is done on cod and redfish. Now they've moved on to skates and monks south of the islands. In order to comprehend the damage they did you had to witness it and there was no better way than to be a winter gillnetter."

Before accepting the notion that seals are less problematic in the winter, perhaps it is more correct to say that they affect fewer people in the winter. In either case, these results and anecdote suggest that seasonality could have an important role in forming perceptions of this issue, which should be considered in further research.

Assessment of Economic Cost Perceptions

In 2012, nearly $2,000,000 USD in costs due to interactions with seals were reported by 37 respondents; presumably this figure would be larger if all respondents completed this portion of the survey. Time and effort constituted the largest proportion of all economic costs for fishermen due to gray seals. A number of respondents indicated having abandoned fisheries due to the burden imposed by seals, and costs of abandonment, in terms of potential earnings from forgone fisheries, were stated as lost time and effort. These effects were most commonly reported in gillnet fisheries, in

addition to the few weir fisheries represented in the survey. Respondents who seasonally crewed on groundfish boats that no longer operate, allegedly due to seal predation, also noted deficits in general income. That seals may displace fishing effort is a fear that resonates with fishermen, as one respondent claimed:

> "[I see] many thousand hauled out on Monomoy Island and [know] a few miles away a 300 year old fishery was ended (weir fishery) due to them. How long before my fishery ends?"

Understanding that the influx in seals could influence fishermen livelihoods, identifying alternative sources of income could be a viable means to alleviate some of these large opportunity costs. Perhaps conducting a cost/benefit analysis of various fisheries or gear types could help elucidate efficient ways for fishermen to transition from fisheries with great cost repercussions due to seals to those with fewer or benign costs. This reallocation of effort could be seasonal (i.e. in the summer) to coincide with times when seal interactions might have the greatest impacts on particular fisheries.

Depredation had the greatest impact on gillnet fisheries, over $300,000 reported by 19 respondents. Relatedly, Rafferty *et al.* (2012) found depredation by harbor seals and spiny dogfish to generate only small amounts of losses in gillnet fisheries, 3.64% of market value. While the potential market value of catch was not calculated in this study, this cost estimate suggests that depredation by gray seals could present substantial financial losses for gillnet fishermen. Further, considering that the financial cost estimated in this study pertains to a one-year period, the costs of gray seal predation could certainly accumulate over years and even decades, as one respondent stated:

> "In the late 90's while gillnetting for cod 12 miles from Chatham I witnessed the loss of an estimated 1,000 pound string of cod due to seals eating the [bellies] out of every fish in the string. It has been a downward spiral of destruction ever since then."

While the effects of depredation were exceeded by opportunity costs, the frequency that depredation occurs could be a cause for concern. As gillnet fisheries are noted to be more susceptible to marine mammal bycatch (Read *et al.* 2005), they may also be more susceptible to depredation, as one respondent mentioned:

> "It's disturbing to haul a 10 net set of gillnets on a 24 hour soak and pick out only bones on what would have been a 3,000 pound set of wings. This happens all too often."

Overall, this research presented only a cursory look into the economic costs posed by gray seal interactions with fisheries. This study could benefit from the addition of control measures to validate responses. Financial costs of seal interactions were self-reported, which could have led to inflation in estimates. Instituting a control measure, for instance by accompanying fishermen on trips or cross-checking reports with observer reports or vessel trip reports, could help identify biases in reported information. However, while any accountability measure would produce a more reliable estimate, it would also seriously infringe on respondent privacy. Despite the potential for inaccuracies resulting from the present protocol, the cost estimates generated could be indicative of the actual proportions of costs caused by particular sources or incurred by particular gear types.

Data Collection and Information Outlook for Gray Seals

Respondent estimates of the local seal population size support the fact that the population has increased substantially over the years. The majority of population estimates surpassed the minimum estimate provided by the latest gray seal stock assessment (NMFS 2012), suggesting that fishermen could be more acutely aware of the present state and rate of increase of the population than government sources that use outdated information and claims of uncertainty with respect to population size and growth rates.

Integrating fishermen into data collection procedures could help improve the present state of data and the credibility of government information, both of which are perceived to be of poor qualities. The majority of respondents felt that collecting data on gray seals is an important undertaking, and many indicated their willingness to participate in research efforts by accommodating scientists or collecting data themselves. Respondents indicated a general dissatisfaction with the quality of fisheries information provided by government entities while ranking their own knowledge as superior. Perhaps the quality of government information is perceived as such due to the time lags in disseminating new information about the gray seal stock.

A brief examination of all gray seal stock assessments reveals that NMFS lacks sufficient information to manage gray seals as mandated by the MMPA (Table 12). The 1995 and 1998 stock assessments provided official estimates of a minimum population size for the U.S. stock based on a 1994 count of gray seals on Muskeget and Monomoy Islands, but from 1999 onward stock assessments failed to provide a minimum estimate due to incomplete information. Scientists recognized that the U.S. stock includes gray seals that immigrated to U.S. waters from Sable Island, and the unknown rate of immigration prevents the approximation of a viable minimum population estimate, much less a complete picture of population dynamics. Despite providing unofficial counts for

Table 12. Gray seal stock assessments, 1995 - 2012

Stock Assessment Year	Muskeget and Monomoy Minimum Count	Official U.S. Minimum Estimate	Canada Minimum Estimate	PBR (US)	Population Trend	Status relative to OSP
1995	2,035 (1994 count)	2,035	143,000	122	Likely Increasing, but unknown	Unknown
1998	2,010 (1994 count, corrected)	2,010	143,000	121	Likely increasing, but rate of increase unknown	Unknown
1999	2,010	Unknown	143,000	Unknown	“”	Unknown
2000	5,611 (1999 count)	Unknown	143,000	Unknown	“”	Unknown
2001	5,611	Unknown	143,000	Unknown	“”	Unknown
2002	5,611	Unknown	143,000	Unknown	“”	Unknown
2003	5,611	Unknown	143,000	Unknown	“”	Unknown
2005	5,611	Unknown	195,000	Unknown	“”	Unknown
2006	5,611	Unknown	125,541 to 169,064	Unknown	“”	Unknown
2008	5,611	Unknown	125,541 to 169,064	Unknown	“”	Unknown
2009	5,611	Unknown	125,541 to 169,064	Unknown	“”	Unknown
2010	5,611	Unknown	125,541 to 169,064	Unknown	“”	Unknown
2011	5,611	Unknown	125,541 to 169,064	Unknown	“”	Unknown
2012	15,756 (2011 count)	Unknown	348,999	Unknown	“”	Unknown

*All stock assessments are publically available at: http://www.nmfs.noaa.gov/pr/sars/species.htm#phocids

the population on Muskeget and Monomoy Islands based on best information and acknowledging that the population is likely increasing, these stock assessments failed to produce values of OSP and PBR, which are necessary for the management of the stock per the MMPA, due to this missing immigration factor.

This review of stock assessments also illustrates the time lag in quantifying stock size. From 2011 to 2012, the minimum estimate for Canada's stock more than doubled, while the minimum count of the Muskeget and Monomoy stock nearly tripled (Table 12). The 2012 estimate of 15,756 gray seals for Muskeget and Monomoy, based off a 2011 count, emerged after a decade of stock assessments used the 5,611 minimum figure, based off a 1999 count; surely the population was not the same each year between 2000 and 2011. This scientific lag, accompanied by the inability to produce official minimum estimates, sufficiently hinders NMFS's ability to appropriately manage the U.S. gray seal stock toward the primary objective of the MMPA, ecosystem health and stability.

A U.S. Government Accountability Office (U.S. GAO 2008) study highlighted the many inefficiencies of marine mammal management. In particular, it showed that NMFS routinely uses dated or deficient stock data to calculate permissible levels of incidental take, and that TRPs were non-existent for nearly half of marine mammal stocks that require one (U.S. GAO 2008). NMFS, however, may not be the sole entity to blame for the poor state of information. The MMPA requires instances of marine mammal interactions and bycatch to be reported (Sec. 118(e)), although it has been noted that very few commercial fishermen voluntarily report such occurrences (Read *et al.* 2005). As a result, NMFS regularly generates estimates from observer reports, which capture only a small proportion of interactions to represent actual conditions. Perhaps encouraging fishermen to report incidental catches more frequently could lead to an improved understanding of the stock from which management can be derived. Conversely, increased rates of reporting could also produce less desirable results for fishermen, as it could reveal fishing as more significant threat to the seal stock and lead to more stringent fishing restrictions. Regardless, to understand the full suite of impacts presented by gray seals, an integrated system for data collection should be established to mobilize fishermen knowledge and capacity to help improve the present state of information.

Management Outlook for Gray Seals

Respondents overwhelmingly believed that gray seals should be managed in Cape Cod, and that such management should be performed in the best interest of fisheries and the ecosystem. This reflects the perception held by the majority of respondents, that seals compromise the health and function of the marine ecosystem, and especially fisheries, as summarized by one respondent:

> "Fish stocks will not recover until [the gray seal] population is controlled regardless of fishing pressure. They need 100,000's of marketable fish to sustain."

The MMPA recognizes management to occur on a spectrum between complete protection and regulated taking (Sec. 3(2)). At present, the MMPA forbids any regulated taking of gray seals, with exception to incidental takes in commercial fisheries (Sec. 118) and intentional, non-lethal attempts to deter marine mammals from affecting gear and catch (Sec. 101(a)(4)(A)(i)). Given the current provisions of the MMPA, perhaps the most practical way to establish a management regime is through the transfer of management authority from federal to state entities (Sec. 109). This would require the Commonwealth of Massachusetts to develop and implement a management program consistent with MMPA goals that upholds principles of OSP and humane taking (Sec. 109(b)).

More broadly, the MMPA can conditionally allow for the taking of marine mammals based on the best scientific evidence available, so long as taking benefits ecosystem health and function without compromising the marine mammal stock (Sec. 103(a)). As such, the MMPA would allow for a reduction of Cape Cod's gray seal population if the best scientific evidence available shows that stock's function will not be compromised and ecosystem health and stability will benefit. Upon brief review, the present state of information about gray seals and their impacts on the Cape Cod ecosystem is critically deficient. While incomplete stock information might disadvantage marine mammals stocks that need protection (Roman *et al.* 2013), in this case the poor state of gray seal information could prevent the necessary management of a potentially overpopulated stock. Facing a similar problem, Canada's Standing Senate Committee on

Fisheries and Oceans contended that bickering about the exact nature of gray seal impacts on fishing should not prevent intervention, stating, "A wait and see approach would be insufficient to allow the recovery of many of the groundfish stocks" (SSCFO 2012). By its very nature, the MMPA prefers a wait and see approach over using imperfect information to inform management.

Even if deemed permissible according to the MMPA, any management of seals in the U.S. would be met by considerable public and political backlash. A 1999 survey of 1,000 Americans indicates that less than 10% of the public supports the use of lethal means to mitigate conflicts between marine mammals and fisheries (Kellert 1999). Further, the survey shows that, while the public sympathizes for the plight of fishermen (60% object to penalizing commercial fishermen that unintentionally harm marine mammals), 60% of respondents disapprove of a cull intended to reduce seal-fishery competition for fish. Physical distance from the problem may also influence perceptions of gray seals, as the majority of people opposed to a cull likely do not live in fishing centers (Gulland 1987). Regardless of rationale or proximity to marine mammal conflicts, it is clear that the American public favors marine mammal conservation; it is no coincidence that the United States has the strongest law protecting marine mammals in the world.

Interpretation of Overlap Analysis

The spatial overlap analysis showed that gray seals and fisheries are more likely to overlap, and thus interact, in summer months than winter months. This finding seems plausible when observing the seasonal distributions in effort by seals and fisheries, which is concentrated near shore in summer months and dispersed further offshore in the winter. These results, however, must be interpreted conservatively as they only reflect the effort distributions of eight gray seals and eleven fishermen. If all fishermen behave like these fishermen and all gray seals behave like these gray seals, then overlap and interactions could occur in areas close to shore in the summer and winter, and areas to the south of Nantucket in the winter.

Greater representation and improved resolution of data could provide more insight to the spatial relationship between seal and fisheries efforts. For instance, Cronin *et al*.

(2012) used high resolution fishing data from a vessel monitoring system to compare with gray seal telemetry data within 3 km^2 grid cells and found substantially lower levels of spatial overlap than this study. The size of grid cells used in this study (10' x 10'; ~100 mi^2) may overstate the extent to which fisheries and seals actually overlap in space and compete for resources. However, an analysis at a higher resolution may also show that overlap does in fact occur on finer scales, and further corroborate claims of interactions made by fishermen. While the precise nature of overlap must be determined in a future study, this novel investigation of seal and fisheries interactions indicates the strong potential for problematic interactions between fisheries and gray seals to occur, primarily in the summer.

Considerations for Future Studies

Future studies should be directed at assessing the greater public's perceptions of this issue, especially residents of Cape Cod. Concurrent with fishermen, the public has expressed concern that the gray seal population could compromise water quality, have negative affects to the tourism industry through attracting Great white sharks to the area, and overcrowd beaches. Although preliminary studies have shown that the seal population does not significantly decrease water quality (Gast 2013), the abundance of seals has been cited as the primary factor for the recent increase in Great white shark activity off Cape Cod (Skomal 2013). Conversely, other members of the general public have expressed satisfaction with the population of gray seals. Seal tourism has emerged as a viable economic opportunity, as a number of operations have opened shop on Cape Cod. For instance, the vessel Beachcomber (www.sealwatch.com) runs multiple tours daily, accommodating 29 people per trip at $29 per person. A comprehensive study of human ecology implications would certainly complement the perceptions documented in this study, and further inform ways to address this issue.

Additionally, future studies should determine whether these perceptions of gray seals are uniform across all fisheries or fishermen. Having been constrained by a small sample size, any significant differences in response frequencies, for instance between gillnet fishermen and all others, would be misleading using a simple chi-squared test as test assumptions pertaining to sample size and expected frequencies were often not met.

With such a small sample and non-normal distribution of responses, a Monte Carlo estimate of exact P-value could have been conducted to identify any trends in response frequencies between the two groups (Jeff Johnson, pers. comm.). However, since this research was exploratory in nature and not hypothesis-driven, any sort of difference would have to be interpreted conservatively as hypotheses would be formed with *a posteriori* knowledge of responses. Knowing that fishermen self-identify primarily through gear types and not by the fisheries in which they participate, future surveys should focus on characterizing respondents by primary gear types and leave fisheries as an accessory variable.

V. CONCLUSION

To conclude, this study documented the perceptions held by commercial fishermen about the impacts of gray seals on commercial fisheries. This study confirmed that fishermen do feel that gray seals pose an urgent threat to fishery longevity and fishermen livelihoods, which should be mitigated through improvements in information and management provisions. To an extent, this study also validated fishermen's concerns by demonstrating the potential for spatial overlap to occur between gray seals and commercial fisheries. While the outlook on managing gray seals through controlled removal under the MMPA is bleak, this study provides valuable insights for understanding the views held by commercial fishermen, a key stakeholder group implicated in this issue, which should be considered when weighing options for mitigating interactions between gray seals and commercial fisheries in Cape Cod.

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VIII. APPENDICES

Appendix A. Social Perception Survey Consent Form and Instrument

Appendix B. Fishing Effort Survey Consent Form and Instrument

FISHERMEN SEAL SURVEY

The Cape Cod Commercial Fishermen's Alliance (formerly the Cape Cod Commercial Hook Fishermen's Association) is conducting this research to quantify the financial impacts of gray seals on the local commercial fishing fleet and to gauge the fleet's positions on seal research and management. The primary purpose of this survey is to inform the Fishermen's Alliance. Since this study is a joint-effort among multiple collaborators, however, we ask permission for other involved parties to use survey responses. Chase Gruber, a Master's student at Duke's Nicholas School of the Environment (NSOE), would like to use the survey results as part of his Master's Research. Owen Nichols and Betty Lentell of the Northwest Atlantic Seal Research Consortium would like to use results of this survey in their research of seal and fisheries interactions.

Participation in this research is completely voluntary. If you wish to skip any questions, please feel free to do so. The survey consists of 27 multi-part questions and should take 15 minutes to complete. Survey responses will be analyzed in aggregate – identities will not be associated with responses. However, names of all respondents will be listed in an appendix attached to the compilation of the responses. If wish to have your name removed from this list, we will comply.

If you have any questions about the content of the survey, please contact Chase Gruber at chase.gruber@duke.edu or 970-390-3054 or the Fishermen's Alliance at 508-945-2432. If you have questions about your rights as a participant in Chase's research, please contact the Chair of the Duke University Institutional Review Board at ORS-info@duke.edu or 919-660-3030.

By checking below, I acknowledge and agree to the following:

- ☐ Chase Gruber of Duke NSOE, by way of the Fishermen's Alliance, may use the answers I provide.
- ☐ Owen Nichols and Betty Lentell of Northwest Atlantic Seal Research Consortium may use the results of this survey.

Name (Print) _____

Signature_____ Date_____

FISHERMEN SEAL SURVEY

PLEASE READ BEFORE BEGINNING SURVEY

Answer the following questions as ACCURATELY and COMPLETELY as possible. Remember that the purpose of this survey is to benefit YOUR fisheries by asking:

1) HOW ARE SEALS IMPACTING COMMERCIAL FISHERIES?

2) HOW MUCH DO WE KNOW ABOUT SEALS?

3) HOW AND WHY SHOULD SEALS BE MANAGED?

There are no right or wrong answers. Note that questions are relative to the LAST calendar year (January 1 – December 31, 2012) and that "seals" refers to GRAY SEALS, *Halichoerus grypus*.

----------START OF SURVEY----------

1. How many years have you fished *commercially*?

2a. Which *commercial* fisheries did you work in LAST year? Select all that apply.

- ☐ Bluefin Tuna
- ☐ Channeled Whelk (Conch)
- ☐ Dogfish
- ☐ Groundfish
- ☐ Lobster
- ☐ Menhaden
- ☐ Monkfish
- ☐ Quahog
- ☐ Sea Scallop
- ☐ Skate
- ☐ Softshell Clam
- ☐ Squid
- ☐ Striped Bass
- ☐ Other _____

2b. Of the fisheries selected above, which do you consider to be your PRIMARY fishery?

3. What gear do you use in the *commercial* fisheries you work? Select all that apply.

- ☐ Benthic Longline
- ☐ Clam Rake
- ☐ Fish Weir
- ☐ Gillnet
- ☐ Handline (Rod and Reel)
- ☐ Harpoon
- ☐ Pots (Lobster or Conch)
- ☐ Scallop Dredge
- ☐ Trawl
- ☐ Other _____

4a. What is the length of the *commercial* vessel you fished from most LAST year?

4b. What is your position (i.e. captain, crew, owner/operator, etc.) on this *commercial* vessel?

FISHERMEN SEAL SURVEY

5. Which month(s) did you fish *commercially* LAST year? Select all that apply.

☐ January	☐ July
☐ February	☐ August
☐ March	☐ September
☐ April	☐ October
☐ May	☐ November
☐ June	☐ December

6. Using the scoring system below, indicate the number of seals you saw while *commercially* fishing each month LAST year, NOT INCLUDING those onshore.

1 = 0-10 seals
2 = 10-100 seals
3 = 100-500 seals
4 = 500-1,000 seals
5 = 1,000+ seals

Enter 0 or leave blank months you did not fish.

____ January	____ July
____ February	____ August
____ March	____ September
____ April	____ October
____ May	____ November
____ June	____ December

7. How would you describe the number of seals you saw IN THE PAST while fishing versus the number of seals you see NOW while fishing?

Many more IN THE PAST	More IN THE PAST	Same Amount	More NOW	Many more NOW
1	2	3	4	5

8. To the best of your ability, ESTIMATE the total population size of seals inhabiting the Cape and Islands and its waters.

9. Which of the following describe the GREATEST IMPACTS of seals on *commercial* fishing? **SELECT THE TOP 3 IMPACTS**; If none apply, please mark one of the last choices.

- ☐ Seals feed on forage fish necessary for commercial fish stocks to rebuild.
- ☐ Seals host parasites that infest fish.
- ☐ Seals damage and/or destroy fishing gear.
- ☐ Seals influence fishermen to change their fishing plans.
- ☐ Seals feed on commercial fish stocks.
- ☐ Seals cause time delays in fishing.
- ☐ Seals feed on fish captured in gear.
- ☐ Other _____

☐ Seals have no effect on commercial fishing. ☐ NOT SURE

FISHERMEN SEAL SURVEY

10. Using the scale below, RATE your level of CONFIDENCE in your ability to distinguish SEAL bite marks from bite marks of OTHER species?

Not at all Confident	Of little Confidence	Somewhat Confident	Confident	Very Confident
1	2	3	4	5

11. In which months did seals have the MOST NOTICEABLE impact on your *commercial* fishing LAST year? **SELECT THE TOP 3 MONTHS;** If none apply, please mark the last choice.

- ☐ January
- ☐ February
- ☐ March
- ☐ April
- ☐ May
- ☐ June
- ☐ July
- ☐ August
- ☐ September
- ☐ October
- ☐ November
- ☐ December

☐ Seals had no impact on my commercial fishing.

STOP

READ BEFORE CONTINUING

On the REVERSE SIDE OF THIS PAGE, you will find a table like the one shown below. READ THE DIRECTIONS at the top of the table before filling it out. NOTE THAT ALL STATEMENTS REFER TO 2012.

EXAMPLE TABLE

Let's say I only fished lobster, striper, and monkfish in 2012. From the table below, Box 1A reads, "On average, it cost me $1000 to leave the dock when I fished lobster in 2012," and Box 4C reads, "Seals ate $3000 worth of monkfish from my gear in 2012."

To the best of your ability, complete the following statements as they apply to the fisheries you worked **in 2012.** If a statement does not apply to a fishery or gear type, please skip.	**Of the fisheries you worked in 2012 (Question 2a), LIST the 3 YOU THINK SEALS IMPACTED THE MOST in boxes A-C.**		
	A Lobster	**B** Striper	**C** Monkfish
1 On average, it cost me $____ to leave the dock (in terms of ice, fuel, gear, bait, etc.) in this fishery.	$1000	$500	$1500
2 I took ____ (number) *commercial* trips in this fishery.	150	50	80
3 Seals ate fish from my gear on ___% of my *commercial* trips in this fishery.	0%	30%	40%
4 Seals eating fish from my gear cost me $____ in this fishery.	$0	$1000	$3000

12. 1) FILL IN Column Headers A-C with the TOP 3 fisheries impacted by seals that YOU WORKED IN 2012. If you participated in 3 or fewer fisheries in 2012, list them all and leave any remaining columns blank.
2) To the best of your ability, complete the statements in the left-hand column as they relate to Fisheries A-C. Remember, ESTIMATION IS ENCOURAGED. If a statement does not apply for a fishery or gear type, skip it.

	2012 FISHERY INFORMATION	A	B	C
1	On average, it cost me $____ to leave the dock (in terms of fuel, ice, bait, gear, etc.) in this fishery.			
2	I took ____ (#) of commercial trips in this fishery.			
3	Seals ate fish from my gear on ____% of my commercial trips in this fishery.			
4	Seals eating fish I caught cost me $____ in this fishery.			
5	Seals damaged the following gear:			
6	Repairing and/or replacing this gear cost me $____.			
7	Any portion of my catch was infested with seal worm on ____% of my trips in this fishery.			
8	Catch infested with seal worm cost me $____.			
9	I lost ___ (#) man-hours due to seals (e.g. picking unmarketable fish, releasing seals from gear, etc).			
10	I lost ____ (#) days in this fishery because of seals.			
11	Time and fishing opportunities lost due to seals cost me $____.			
12	I traveled as far as ____ miles from my normal fishing grounds to avoid seals.			
13	I spent $____ extra on fuel to avoid seals.			
14	Please list any other seal-associated costs you experienced in 2012:			

FISHERMEN SEAL SURVEY

LOCAL SEAL RESEARCH AND DATA COLLECTION

13. In your opinion, is it important to collect data on the local seal population?

☐ YES ☐ NO

14. Using the scale below, CIRCLE the value that best describes your opinion of the CURRENT state of data on the local seal population?

Poor	Questionable	Fair	Good	Excellent
1	2	3	4	5

15. Using the scale below, RATE the following resources on the QUALITY of fisheries information they provide.

	Poor	Questionable	Fair	Good	Excellent
Government	1	2	3	4	5
University Researchers	1	2	3	4	5
Contracted Scientists	1	2	3	4	5
Fishermen	1	2	3	4	5

16. Would you be willing to host RESEARCHERS on your boat DURING *commercial* fishing trips (assuming space is available) to collect data for studies of seal/fishery interactions?

☐ YES ☐ NO

17a. Would you be WILLING and ABLE to document seal sightings while fishing *commercially*?

☐ YES ☐ NO

17b. If NO to 17a, why not? Select all that apply.

☐ UNWILLING ☐ UNABLE

18. Would you be able to collect the following data immediately after sighting seals while fishing *commercially*?

Date and time of sighting	☐ YES	☐ NO
Approximate location of sighting	☐ YES	☐ NO
Approximate number of seals	☐ YES	☐ NO
Physical size of seals	☐ YES	☐ NO
General description of seal behavior	☐ YES	☐ NO
Distinguishable markings s (tags, wounds)	☐ YES	☐ NO

FISHERMEN SEAL SURVEY

19a. Would you be comfortable SHARING your seal sighting information ON THE INTERNET?

☐ YES ☐ NO

19b. If NO to 19a, why would you be uncomfortable SHARING your seal sighting information ON THE INTERNET? Select all that apply.

- ☐ Confidentiality concerns
- ☐ Unwilling to disclose information related to fishing
- ☐ Unsure of how the information I provide will be used
- ☐ Not confident using computers to upload or enter data
- ☐ Other _____

SEAL MANAGEMENT OUTLOOK

20. Should seals be managed on the Cape and Islands?

☐ YES ☐ NO

21. Using the scale below, SCORE the following interests according to their IMPORTANCE in deciding how to MANAGE seals on Cape Cod?

	Not at all Important	Of little Importance	Somewhat Important	Important	Very Important
Best interest of the ECOSYSTEM	1	2	3	4	5
Best interest of the FISHERIES	1	2	3	4	5
Best interest of the TOURISM INDUSTRY	1	2	3	4	5
Best interest of the SEAL POPULATION	1	2	3	4	5
Best interest of the LOCAL COMMUNITY	1	2	3	4	5

22. . Using the scale below, CIRCLE the value that best describes your feelings about the CURRENT population of seals on and around Cape Cod.

Far too few	Slightly too few	Ideal amount	Slightly too many	Far too many
1	2	3	4	5

23. Complete this sentence: Seals HELP an ecosystem by:

24. Complete this sentence: Seals HARM an ecosystem by:

FISHERMEN SEAL SURVEY

25. In your opinion, what role should the FISHERMEN'S ALLIANCE play in managing the Cape's seal population?

26. In your opinion, what role should FISHERMEN play in managing the Cape's seal population?

27a. Is there a seal "problem" on the Cape and Islands?

☐ YES ☐ NO

27b. **FREE RESPONSE** Describe a specific event that helped form your perception of the local seal population. How has your perception changed over the years? Any other comments regarding seals? You may use the back of this page if you need additional space.

DEMOGRAPHIC INFORMATION

Please indicate your sex:

☐ Male
☐ Female
☐ Not declared

Please indicate your age:

☐ 20 or younger
☐ 21-25
☐ 26-30
☐ 31-40
☐ 41-50
☐ 51-60
☐ 60+

DATE OF COMPLETION:_____

----------END OF SURVEY----------

FISHING EFFORT MAP INFORMATION RELEASE -- FEBRUARY 24, 2014

ALL INFORMATION COLLECTED IN THIS WORKSHOP WILL BE ANONYMOUS AND AGGREGATED. IDENTITIES WILL NOT BE USED IN ANY PUBLICATIONS OR LINKED TO INDIVIDUAL RESPONSES. INFORMATION MAY BE MADE PUBLICLY ACCESSIBLE IN CHASE GRUBER'S MASTERS PROJECT AND JERRY MOXLEY AND DR. DAVID JOHNSTON'S CONTINUED RESEARCH ON GRAY SEALS.

BY SIGNING BELOW, I ACKNOWLEDGE THAT CHASE GRUBER, JERRY MOXLEY, AND DR. DAVID JOHSNTON CAN USE THE INFORMATION I PROVIDE.

	PRINT NAME	SIGNATURE
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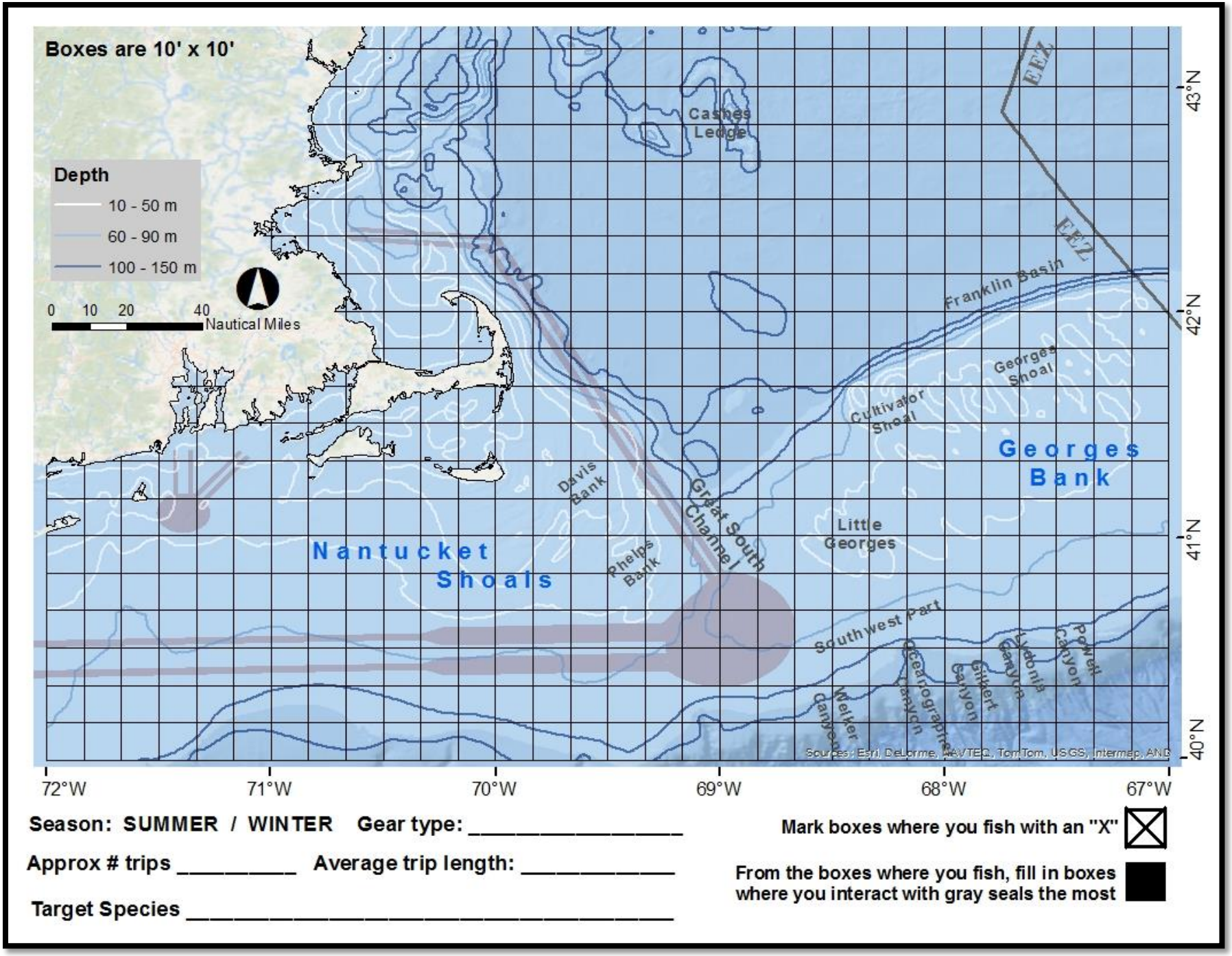

Season: SUMMER / WINTER **Gear type: _____**

Approx # trips _____ **Average trip length: _____**

Target Species _____

Mark boxes where you fish with an "X" ☒

From the boxes where you fish, fill in boxes where you interact with gray seals the most ■